PROCEEDINGS
OF THE
NATIONAL ACADEMY OF SCIENCES
INDIA
1941

PART IV] VOL. XI [Pp. 69—105 & 85—103

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November, 1941

ALLAHABAD

PUBLISHED BY THE COUNCIL

Price Rs. 2 (India); Rs. 2/8 (Foreign)

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PROCEEDINGS

OF THE

NATIONAL ACADEMY OF SCIENCES

INDIA

Part 4] November, 1941 [Volume 11

THE ACTION FORM AND JACOBI'S LAST MULTIPLIER

By K. Nagabhushanam

Mathematics Department, Andhra University, Waltair

Communicated by Dr. G. Gopalarao

(Received on September 18, 1939)

SUMMARY

If the manifold of states and time is affinely connected,

i) $div.\ \sqrt{A^{ii}}=0$,

ii) $X_i \sqrt{A^{ii}}$ is a last multiplier of Jacobi for (9),

iii) $\sqrt{A^{ii}}\ \varepsilon_{a_1\ a_2 \cdots a_{2n}i}$ is a Stokes tensor,

and *iv)* ω_{2n+1} and ω_{2n} are two invariant integrals attached to the trajectories and connected with the last multiplier of Jacobi for the differential equations of the trajectories.

In affine space A_m with symmetric connection, I have elsewhere* proved that if V^i be a vector density, and if

$$div\ V^i = V^i,\ i = \frac{\partial V^i}{\partial x^i} = 0, \qquad (1)$$

where the comma denotes covariant differentiation with respect to the symmetric connection, and a repeated index stands for summation,

$$V^i\ \varepsilon_{a_1 a_2 \cdots a_{m-1} i}\ \dagger$$

is a Stokes tensor.‡ If

$$V^i = M\xi^i$$

where M is a scalar density, then M is a Jacobi's last multiplier§ for the system of differential equations

$$\frac{dx^1}{\xi^1} = \frac{dx^2}{\xi^2} = \cdots\cdots = \frac{dx^m}{\xi^m} \qquad (2)$$

* *A property of Jacobi's last multiplier*, Jour. Lond. Math. Soc, Vol. 9, Part I, pp. 13—15.

† For the Epsilon tensor see O. Veblen, *Invariants of Quadratic Differential Forms*, (Cambridge Tract), p. 25.

‡ For a definition of the Stokes tensor, see O. Veblen, *Ibid.* p. 65.

§ Encyklopadie der math. Wiss. II A 4, p. 248.

Adopting the notation of a previous paper* 'On the form $\varepsilon p_r\, dq^r - H dt$' the equations of motion of a conservative h-olonomic dynamical system can be written as

$$a_{ik}\, dx^k = 0, \qquad (i, k = 1, 2, \ldots . 2n+1), \qquad . \quad . \quad . \quad . \quad . \quad (3)$$

where $a_{ik} = \frac{\partial X_i}{\partial x^k} - \frac{\partial X_k}{\partial x^i}$, and $X_i\, dx^i$, the Pfaffian form of action for a displacement (dx^i) is of class† $2n+1$ in the $2n+1$ variables of the *manifold of states and time*. If A^{ik} are the cofactors of a_{ik} in the determinant $|a_{ik}|$, which is of odd order $2n+1$ and skew-symmetric, the A^{ik} represent a contravariant tensor of weight two. Also we have‡

$$A^{ik} = \alpha^i\ \alpha^k \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where (α^i) is a vector density. It follows that

$$a_{ik}\ \alpha^k = 0, \ (i = 1, 2 \ldots 2n+1) \qquad . \quad . \quad . \quad . \quad (5)$$

Thus the (α^i) is a vector density codirectional with the trajectories. Since the equations form a complete system§ we can choose $2n$ independent first integrals of the system as the first $2n$ variables of a coordinate system. In such a system of *Integrals-coordinates*.

$$a_{i\,(2n+1)} = 0\|, \ (i = 1, 2, \ldots 2n+1) \qquad . \quad . \quad . \quad . \quad (6)$$

so that the matrix $|a_{ik}|$ becomes

$$\begin{vmatrix}
0 & \cdots & 0 & 1 & 0 & \cdots & 0 & 0 \\
0 & \cdots & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & \cdots & 0 & 0 & 0 & 1 & 0 & 0 \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
0 & \cdots & 0 & 0 & \cdots & 0 & 1 & 0 \\
-1 & \cdots & 0 & 0 & \cdots & 0 & 0 & 0 \\
0 & -1 & \cdots & 0 & 0 & \cdots & 0 & 0 \\
0 & \cdots & 0 & -1 & 0 & \cdots & 0 & 0 \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
0 & \cdots & 0 & -1 & 0 & \cdots & 0 & 0 \\
0 & \cdots & 0 & 0 & \cdots & 0 & 0 & 0
\end{vmatrix}$$

*Proc. Ind. Ac. Sci., Bangalore, Vol. I, No. 8, pp. 555—561.

†The Class of $X_i\, dx^i$ is the rank of the matrix $|a_{ik} ; x_k|$

‡Gerhard Kowalewski: *Determinant-theorie*, p. 124.

§E. Goursat: *Lecons sur le probléme de Pfaff*, p 27.

‖K. Nagabhushanam: *On the form* $\Sigma p_r\, dq^r - H dt$, *Ibid.*, p. 557.

Hence, the only non-vanishing A^{ik} is $A^{(2n+1)(2a+1)}$, which is 1. Thus we have by (4)

$$\alpha^j = 0, (j=1, 2 \ldots 2n), \alpha^{2n+1} = \pm 1 \quad . \quad . \quad . \quad . \quad (7)$$

Now the manifold of states and time may be supposed to be affinely connected by a symmetric connection* for which the dynamical trajectories are the transversals of parallelism of $2n$ other independent vector fields. Then on the Integrals-coordinate system in A_{2n+1} in which the trajectories may without loss of generality be taken as the parametric lines of x^{2n+1}, we have from (7)

$$div\ \alpha^i = \frac{\partial \alpha^{2n+1}}{\partial x^{2n+1}} = 0$$

Hence in all systems of coordinates connected with these non-singularly

$$div \sqrt{A^{ii}} = div\ \alpha^i = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Therefore

$$\sqrt{A^{ii}}\ \varepsilon_{a_1 a_2 \ldots . a_{2n}}\ i$$

is derivable as a Stokes tensor of an alternating one of order $2n-1$. Also the scalar density $X_i\ \alpha^i = X_i \sqrt{A^{ii}}$ is a Jacobi's last multiplier for the equations

$$\frac{dx^1}{\alpha^1/X_i\,\alpha^i} = \frac{dx^2}{\alpha^2/X_i\,\alpha^i} = \ldots\ldots = \frac{dx^{2n+1}}{\alpha^{2n+1}/X_i\,\alpha^i}, \quad . \quad . \quad . \quad . \quad (9)$$

for

$$div \left(X_i\ \alpha^i \,.\, \frac{\alpha^k}{X_l\ \alpha^l} \right) = div\ \alpha^k = 0.$$

---

*The tensor properties of Jacobi's last multiplier depend upon the symmetric nature of the connection. A suitable choice of the connection, making the trajectories the transversals of parallelism is given by

$$\Gamma^l_{ii} = f_i, \ (i=1, 2, \ldots . 2n),$$

without summation, the f's being arbitrary, and all other coefficients zero, in the integrals-coordinates. The components of the jth. vector of the $2n$ independent fields may be taken as

$$v^i_{(j)} = \varphi^i\ \delta^j_i\ , \ (j=1, 2, \ldots 2n),$$

where the φ's are arbitrary. The jth. vector field is taken tangential to the parametric curves of x^j. Let us consider first vector field $(\varphi^1, 0, 0, \ldots 0)$. The result of covariant differentiation with respect to the proposed connection is

$$\bar{\varphi}^i = \frac{d\varphi^i}{dx^{2n+1}} + \Gamma^i_{lm} \frac{dx^l}{dx^{2n+1}}\ \varphi^m = \left[\frac{d\varphi}{dx^{2n+1}} + f_i \frac{dx^i}{dx^{2n+1}}\ \varphi^i \right] \delta^i{}_i$$

which may be written as $\lambda\ (\varphi^1, 0, \ldots . 0)$; *i.e.*, the vector remains parallel in the transport. Similarly, the other fields have the trajectories as the transversals of parallelism.

Since $X_i \sqrt{A^{ii}}$ is a Jacobi's multiplier, it follows* that

$$\omega_{2n+1} = \int\int \ldots \int \sqrt{A^{ii}}\ X_i\ dx^1\ dx^2 \ldots dx^{2n+1}$$

and

$$\omega_{2n} = \int\int \ldots \int \left[\begin{array}{c} \sqrt{A^{11}}\ dx^2\ dx^3 \ldots \ldots dx^{2n+1} - \sqrt{A^{22}}\ dx^1\ dx^3 \ldots dx^{2n+1} + \ldots \\ - \ldots\ldots\ldots + \sqrt{A^{(2n+1)\,(2n+1)}}\ dx^1\ dx^2 \ldots dx^{2n} \end{array} \right]$$

are integrals invariants† attached to the equations (8) of the trajectories, ω_{2n} being obtained from ω_{2n+1} by Goursat's E-operation.‡ A repetition of the E-operation on ω_{2n} leads to a form which vanishes identically. It can be seen easily that the $2n$ independent forms in

$$d_i = a_{ik}\, dx^k, \ (i = 1, 2 \ldots 2n+1)$$

are linear divisors of ω_{2n}

---

* E. Goursat, *Ibid.*, p. 221.

† For a complete list of integral invariants see E. Goursat, *Ibid.*, Also see E. Cartan: *Leçons sur les invariants integraux.*

‡ E. Goursat, *Ibid.*, p. 243.

ON FUNCTIONS WHICH ARE FOURIER SINE OR COSINE-TRANSFORMS OF EACH OTHER

By Hari Shanker

Anglo-Arabic College, Delhi

Communicated by Dr. Shri Ranjan

(Received on January 25, 1941)

SUMMARY

The object of this paper is to prove the following Theorem :—

If $\phi(x)=(2\pi)^{-\frac{1}{2}}\,\Gamma(m+1)\,D_n(x)\left\{e^{i\mu\pi}\,D_{-m-1}(ix)+e^{-i\mu\pi}\,D_{-m-1}(-ix)\right\}$

and $\psi(x)=n!\,e^{-\frac{1}{2}x^2}\,x^{m-n}\,\underset{n}{\llcorner}^{m-n}(x^2)$

then $\phi(x)$ and $\psi(x)$ are Fourier Sine or Cosine-transforms of each other according as $\mu=\frac{n+1}{2}$ or $\frac{n}{2}$ where 'n' is a positive integer and 'm' is any number greater than '$n-1$'.

1. In a paper,* published in 1938, R. S. Varma has proved that

$$\text{If } \phi(x) = i\left\{D^2_{-n-1}(ix)-D^2_{-n-1}(-ix)\right\}$$

and

$$\psi(x)=\frac{(-1)^n\,2\pi}{n!}e^{-\frac{1}{2}x^2}\,\llcorner_n(x^2)$$

Then $\phi(x)$ and $\psi(x)$ are Fourier Sine-Transforms† of each other provided that 'n' is a positive integer.

The object of this paper is to prove a more general theorem, which may cover Fourier sine and cosine-transforms into one and may thus yield the above-mentioned result as one of its corollaries.

Theorem :—

If $\phi(x)=(2\pi)^{-\frac{1}{2}}\,\Gamma(m+1)\,D_n(x)\left\{e^{i\mu\pi}\,D_{-m-1}(ix)+e^{-i\mu\pi}\,D_{-m-1}(-ix)\right\}$

and $\psi(x)=n!\,e^{-\frac{1}{2}x^2}\,x^{m-n}\,\underset{n}{\llcorner}^{m-n}(x^2)$

then $\phi(x)$ and $\psi(x)$ are Fourier sine or cosine-transforms of each other according as $\mu=\frac{n+1}{2}$ or $\frac{n}{2}$, provided that n is a positive integer and m is greater than $n-1$.

---

* R. S. Varma : Quarterly Jour. of Maths. (Oxford Series) 9, 1938, 203–5.

† $\phi(x)$ and $\psi(x)$ are said to be Fourier sine-transforms of each other when $\phi(x)=\sqrt{\frac{2}{\pi}}\int_0^\infty \psi(t)\sin xt\,dt$ and $\psi(x)=\sqrt{\frac{2}{\pi}}\int_0^\infty \phi(t)\sin xt\,dt$. Similar definition holds for Fourier cosine-transforms.

2. In order to demonstrate the truth of this theorem we start with the integral

$$\int_0^\infty e^{-t^2/2 - zt}\ t^{m-n} \underset{n}{\overset{m-n}{\llcorner}} (t^2)\ dt$$

and find by virtue of the well-known results

$$\underset{n}{\overset{\alpha}{\llcorner}} (x) = \Gamma(n+\alpha+1) \sum_{r=0}^{n} \frac{(-x)^r}{(n-r)!\, r!\, \Gamma(\alpha+r+1)} \tag{2·1}$$

$$\text{and} \int_0^\infty e^{-t^2/2 - zt}\ t^n\, dt = \Gamma(n+1)\, e^{\frac{1}{4}z^2}\, D_{-n-1}(z), \qquad \mathrm{R}(n+1) > 0 \tag{2·2}$$

that

$$\int_0^\infty e^{-t^2/2 - zt}\ t^{m-n} \underset{n}{\overset{m-n}{\llcorner}} (t^2)\ dt$$

$$= \Gamma(m+1) \sum_{r=0}^{n} (-1)^r \int_0^\infty \frac{e^{-t^2/2 - zt}\ t^{m-n+2r}}{(n-r)!\, r!\, \Gamma(m-n+r+1)}\ dt.$$

$$= \Gamma(m+1)\, e^{\frac{1}{4}z^2} \sum_{r=0}^{n} \frac{(-1)^r\, \Gamma(m-n+2r+1)}{(n-r)!\, r!\, \Gamma(m-n+r+1)} \cdot D^{(z)}_{n-m-2r-1} \tag{2·3}$$

To sum this series we observe* that for all values of z and m

$$\frac{\Gamma(m+1)}{\Gamma(m-n+1)}\, e^{\frac{1}{4}z^2}\, D_{m-n}(z) = (-1)^n \sum_{r=0}^{n} i^{n-r}\, {}^nC_r\, D_{m+r}(z)\, D_{n-r}(iz) \tag{2·4}$$

Hence by using this result we find after a little simplification that†

$$i^{-n}\ D_n(iz)\, D_{-m-1}(z)$$

$$= \Gamma(n+1)\, e^{-\frac{1}{4}z^2} \sum_{r=0}^{n} \frac{(-1)^r\, \Gamma(m-n+2r+1)}{(n-r)!\, r!\, \Gamma(m-n+r+1)}\, D^{(z)}_{n-m-2r-1} \tag{2·5}$$

and

$$i^n \cdot D_n(z)\, D_{-m-1}(iz)$$

$$= \Gamma(n+1)\ e^{-\frac{1}{4}z^2} \sum_{r=0}^{n} \frac{(-1)^r\, \Gamma(m-n+2r+1)\, D^{(iz)}_{n-m-2r-1}}{(n-r)!\, r!\, \Gamma(m-n+r+1)} \tag{2·6}$$

Since $D_n(-z) = (-1)^n\ D_n(z)$ when n is integral.

---

*H. Shanker: Jour. Ind. Math. Soc. (2), Vol. 3, 226–30.

†H. Shanker: Proc. Ben. Math. Soc. (2) 1940, (2.5) and (2.6) have been obtained by a different method in this paper.

Now substituting the value from (2.5) in (2.3) we obtain

$$n! \int_0^\infty e^{-t^2/2 - zt}\, t^{m-n} \underset{n}{\lfloor^{m-n}} (t^2)\, dt$$

$$= \Gamma(m+1)\, e^{\frac{-in\pi}{2}}\, D_n(iz)\, D_{-m-1}(z) \quad . \quad (2{\cdot}7)$$

Since $f(x) \doteqdot \phi(p)$ when $\phi(p) = p\int_0^\infty e^{-px} f(x)\, dx$, provided that integral converges, we have from (2·7)

$$n!\, e^{-\frac{1}{2}x^2}\, x^{m-n} \underset{n}{\lfloor^{m-n}} (x^2) \doteqdot \Gamma(m+1)\, pi^{-n}\, D_n(ip)\, D_{-m-1}(p) \quad . \quad (2{\cdot}8)$$

which we shall need in the subsequent part of this paper.

3. Replacing z first by iz and then by $-iz$ in (2.7) and adding and subtracting the two results so obtained, $viz.$,

$$n! \int_0^\infty e^{-t^2/2 - izt}\, t^{m-n} \underset{n}{\lfloor^{m-n}} (t^2)\, dt$$

$$= \Gamma(m+1)\, e^{in\pi/2}\, D_n(z)\, D_{-m-1}(iz) \quad . \quad . \quad . \quad (3{\cdot}1)$$

and

$$n! \int_0^\infty e^{-t^2/2 + izt}\, t^{m-n} \underset{n}{\lfloor^{m-n}} (t^2)\, dt.$$

$$= \Gamma(m+1)\, e^{-in\pi/2}\, D_n(z)\, D_{-m-1}(-iz) \quad . \quad . \quad (3{\cdot}2)$$

we obtain respectively

$$\sqrt{\frac{2}{\pi}} \int_0^\infty n!\, e^{-t^2/2}\, t^{m-n} \underset{n}{\lfloor^{m-n}} (t^2) \cos zt\, dt$$

$$= (2\pi)^{-\frac{1}{2}}\, \Gamma(m+1)\, D_n(z) \left\{ e^{in\pi/2}\, D_{-m-1}(iz) + e^{-in\pi/2}\, D_{-m-1}(-iz) \right\} \quad (3{\cdot}3)$$

and

$$\sqrt{\frac{2}{\pi}}\int_0^\infty n!\, e^{-t^2/2}\, t^{m-n}\, \underset{n}{\lfloor^{m-n}}(t^2)\sin xt\, dt$$

$$= (2\pi)^{-1/2}\ \Gamma(m+1)\, D_n(x)\left\{ e^{\frac{i(n+1)\pi}{2}}\ D_{-m-1}(ix) + e^{\frac{-i(n+1)\pi}{2}}\ D_{-m-1}(-ix)\right\} \tag{3·4}$$

which furnish Fourier cosine and sine-transforms of $\psi(x)$ respectively.

4. Now to establish the reciprocal relations between $\phi(x)$ and $\psi(x)$ we note that*

$$\frac{1}{\pi}\int_{-\infty}^{\infty} e^{-\frac{1}{4}t^2}\, x\,(x^2+t^2)^{-1}\ D_{-m-1}(it)\, dt = e^{\frac{1}{4}x^2}\ D_{-m-1}(x). \quad . \quad (4·1)$$

and

$$\frac{i}{\pi}\int_{-\infty}^{\infty} e^{-\frac{1}{4}t^2}\, t\,(x^2+t^2)^{-1}\ D_{-m-1}(it)\, dt = e^{\frac{1}{4}x^2}\ D_{-m-1}(x). \quad . \quad (4·2)$$

Hence expressing $i^n D_n(t) D_{-m-1}(it)$ by (2·6) and integrating term by term with the aid of (4·1) and (4·2) we obtain the generalisations of the above integrals in the forms

$$\frac{i^n}{\pi}\int_{-\infty}^{\infty} D_n(t) D_{-m-1}(it)\ p(t^2+p^2)^{-1}\, dt = i^{-n}\ D_n(ip)\ D_{-m-1}(p). \quad . \quad (4·3)$$

and

$$\frac{i^{n+1}}{\pi}\int_{-\infty}^{\infty} D_n(t) D_{-m-1}(it)\ t(t^2+p^2)^{-1}\, dt = i^{-n} D_n(ip) D_{-m-1}(p). \quad (4·4)$$

Now interpreting both the sides of (4.3) and (4.4) with the help of operational relations

$$\cos at \doteqdot p^2(x^2+t^2)^{-1}\ ;\ \sin xt \doteqdot pt(x^2+t^2)^{-1}$$

and

$$n!\, e^{-\frac{1}{2}x^2}\, x^{m-n}\, \underset{n}{\lfloor^{m-n}}(x^2) \doteqdot \Gamma(m+1) i^{-n}\, p\, D_n(ip)\, D_{-m-1}(p)$$

---

*Hari Shanker: Proc. Ben. Math. Scc. 6, 1924, 11—12.

we get

$$\frac{\Gamma(m+1)\, i^n}{\pi} \int_{-\infty}^{\infty} D_n(t)\, D_{-m-1}(it) \cos xt\, dt$$

$$= n!\, e^{-\frac{1}{2}x^2}\, x^{m-n}\, \underset{n}{\overset{m-n}{\sqsubset}}(x^2) \qquad \ldots \qquad (4{\cdot}5)$$

and

$$\frac{\Gamma(m+1)\, i^{n+1}}{\pi} \int_{-\infty}^{\infty} D_n(t)\, D_{-m-1}(it) \sin xt\, dt$$

$$= n!\, e^{-\frac{1}{2}x^2}\, x^{m-n}\, \underset{n}{\overset{m-n}{\sqsubset}}(x^2) \qquad \ldots \qquad (4{\cdot}6)$$

i.e.,

$$\sqrt{\frac{2}{\pi}} \int_0^{\infty} (2\pi)^{-\frac{1}{2}}\, \Gamma(m+1)\, D_n(t) \left\{ e^{\frac{in\pi}{2}}\, D_{-m-1}(it) + e^{\frac{-in\pi}{2}} \right.$$

$$\left. D_{-m-1}(-it) \right\} \cos xt\, dt$$

$$= n!\, e^{-\frac{1}{2}x^2}\, x^{m-n}\, \underset{n}{\overset{m-n}{\sqsubset}}(x^2) \qquad \ldots \qquad (4{\cdot}7)$$

and

$$\sqrt{\frac{2}{\pi}} \int_0^{\infty} (2\pi)^{-\frac{1}{2}}\, \Gamma(m+1)\, D_n(t) \left\{ e^{i\left(\frac{n+1}{2}\right)\pi}\, D_{-m-1}(it) + e^{-i\left(\frac{n+1}{2}\right)\pi} \right.$$

$$\left. D_{-m-1}(-it) \right\} \sin xt\, dt$$

$$= n!\, e^{-\frac{1}{2}x^2}\, x^{m-n}\, \underset{n}{\overset{m-n}{\sqsubset}}(x^2) \qquad \ldots \qquad (4{\cdot}8)$$

which establish the reciprocal relations between $\phi(x)$ and $\psi(x)$ and consequently with (3.3) and (3.4) prove the theorem enunciated above.

Varma's result follows from the general theorem by taking $m=n$ and $\mu = \frac{n+1}{2}$, and by using the well-known relation*

$$D_n(z) = (2\pi)^{-\frac{1}{2}}\, \Gamma(n+1) \left\{ e^{\frac{in\pi}{2}}\, D_{-n-1}(iz) + e^{\frac{-in\pi}{2}}\, D_{-n-1}(-iz) \right\}$$

* Whittaker and Watson : *Modern Analysis*, 348.

A CERTAIN CONFLUENT HYPER-GEOMETRIC FUNCTION

By B. Mohan

Mathematics Department, Hindu University, Benares

Communicated by Dr. Gorakh Prasad

(Received on January 28, 1941)

SUMMARY

The paper aims at deducing certain properties of a confluent Hyper-geometric function. For instance, if

$$\phi_\nu(x)=\frac{(\frac{1}{2}x)^\nu\sqrt{\pi}}{\Gamma(\nu+1)},\ {}_1F_1(\tfrac{1}{2};\nu+1;-\tfrac{1}{4}x^2),$$

it is shown that

$$\phi'_\nu(x)=\phi_{\nu-1}(x)-\frac{\nu}{x}\phi_\nu(x),$$

$$\left(\frac{x}{2}-\frac{\nu}{x}\right)\phi_\nu(x)=(\nu+\tfrac{1}{2})\ \phi_{\nu+1}-\phi'_\nu,$$

$$\phi''_\nu+\left(\frac{x}{2}+\frac{1}{x}\right)\phi'_\nu+\left(\tfrac{1}{2}-\tfrac{1}{2}\nu-\frac{\nu^2}{x^2}\right)\phi_\nu=0$$

$$\left(\frac{d}{2dx}\right)^m\left(x^n\phi_n\right)=x^{n-m}\ \phi_{n-m},$$

$$\varphi_\nu(x)=\frac{(\frac{1}{2}x)^\nu}{\Gamma(\nu+\frac{1}{2})}\int_0^1\frac{t^{\nu-\frac{1}{2}}}{\sqrt{1-t}}\,e^{-\frac{1}{4}x^2(1-t)}\,dt,$$

and

$$\int_0^\infty x^{\rho-1}\,e^{-ax^2}\,\phi_\nu(bx)\,dx=\frac{b^\nu\,\Gamma(\frac{1}{2}\rho+\frac{1}{2}\nu)}{2^{\nu+1}\,a^{\frac{1}{2}\rho+\frac{1}{2}\nu}\,\Gamma(\nu+1)}\times F\left(\tfrac{1}{2}\rho+\tfrac{1}{2}\nu;\ \nu+1;-\frac{b^2}{4a}\right).$$

The object of this note is to study the properties of a confluent Hyper-geometric function which I have come across while studying Self-Reciprocal Functions.

Recently, I* have proved that the functions

$${}_1F_1\left(\tfrac{1}{2};\tfrac{5}{4}-\tfrac{1}{2}\nu;-\tfrac{1}{2}x^2\right)\quad(\nu>0),$$

$$x^{\nu-\frac{1}{2}}\,e^{-\frac{1}{2}x^2}\ {}_1F_1\left(\tfrac{1}{2};\nu+\tfrac{1}{2};\tfrac{1}{2}x^2\right)\qquad(\nu>\tfrac{2}{3})$$

are self-reciprocal for J_ν transforms. This leads us to an examination of the function

$$\phi_\nu(x)=\frac{(\frac{1}{2}x)^\nu\sqrt{\pi}}{\Gamma(\nu+1)}\ {}_1F_1(\tfrac{1}{2};\nu+1;-\tfrac{1}{4}x^2)\quad\ldots\quad(1.1)$$

$$=\sum_0^\infty\frac{(-1)^r}{2^{\nu+2r}}\frac{\Gamma(\frac{1}{2}+r)\,x^{\nu+2r}}{\Gamma(1+\nu+r)\,\underline{|r}}\quad\ldots\quad(1.2)$$

* Formulæ connecting Self-Reciprocal Functions—in the press.

If we adopt this notation, we shall say that the functions

$$x^{\frac{1}{2}\nu-\frac{1}{4}}\ \phi_{\frac{1}{4}-\frac{1}{2}\nu}\ (x\sqrt{2}) \qquad (\nu>0)$$

$$e^{-\frac{1}{2}x^2}\ \phi_{\nu-\frac{1}{2}}\ (ix\sqrt{2}) \qquad (\nu>\tfrac{2}{3})$$

are self-reciprocal for J_ν transforms.

2. To begin with, the series (1.2) is absolutely and uniformly convergent for all finite x. It is also obvious that

$$\phi_{-\frac{1}{2}}(x)=\sqrt{\frac{2}{x}}\,e^{-\frac{1}{4}x^2} \qquad \ldots\ldots\ldots\ldots \quad (2.1)$$

Now, differentiating (1.2) with respect to x, we have

$$\phi'_\nu(x)=\sum_0^\infty \frac{(-1)^r\Gamma(\frac{1}{2}+r)(\nu+2r)x^{\nu+2r-1}}{2^{\nu+2\gamma}\,\lfloor r\,\Gamma(1+\nu+r)}$$

$$=\sum_0^\infty \frac{(-1)^r\Gamma(\frac{1}{2}+\gamma)\,(2\nu+2\gamma)}{2^{\nu+2r}\lfloor r\,\Gamma(1+\nu+r)}\,x^{\nu+2r-1}-\nu\sum_0^\infty \frac{(-1)^r\Gamma(\frac{1}{2}+r)\,x^{\nu+2r-1}}{2^{\nu+2r}\lfloor r\,\Gamma(1+\nu+r)}$$

$$=\sum_0^\infty \frac{(-1)^r\,\Gamma\,(\frac{1}{2}+r)\,x^{\nu+2r-1}}{2^{\nu+2r-1}\lfloor r\,\Gamma(\nu+r)}-\frac{\nu}{x}\phi_\nu\,(x).$$

Hence $$\phi'_\nu(x)=\phi_{\nu-1}(x)-\frac{\nu}{x}\phi_\nu\,(x). \qquad \ldots\ldots\ldots \quad (2.2)$$

Again, $$\left(\frac{x}{2}-\frac{\nu}{x}\right)\phi_\nu(x)=\left(\frac{x}{2}-\frac{\nu}{x}\right)\sum_0^\infty \frac{(-1)^r\,\Gamma(\frac{1}{2}+r)\,x^{\nu+2r}}{2^{\nu+2r}\lfloor r\,\Gamma(1+\nu+r)}$$

$$=\sum_0^\infty \frac{(-1)^r\,\Gamma(\frac{1}{2}+r)\,x^{\nu+2r+1}}{2^{\nu+2r+1}\lfloor r\,\Gamma(1+\nu+r)}-\nu\sum_0^\infty \frac{(-1)^r\,\Gamma(\frac{1}{2}+r)\,x^{\nu+2r-1}}{2^{\nu+2r}\lfloor r\,\Gamma\,(1+\nu+r)}$$

$$=\sum_0^\infty \frac{(-1)^r\,\Gamma(\frac{1}{2}+r)\,x^{\nu+2r+1}}{2^{\nu+2r+1}\lfloor r\,\Gamma(1+\nu+r}-\sum_0^\infty \frac{(-1)^r\,\Gamma(\frac{1}{2}+r)\,(\nu+2r)}{2^{\nu+2r}\lfloor r\,\Gamma(1+\nu+r)}\,x^{\nu+2r-1}$$

$$+\sum_1^\infty \frac{(-1)^r\,\Gamma(\frac{1}{2}+r)x^{\nu+2r-1}}{2^{\nu+2r-1}\lfloor r-1\,\Gamma(1+\nu+r)}$$

$$=\sum_0^\infty \frac{(-1)^r\,\Gamma(\frac{1}{2}+r)\,x^{\nu+2r+1}}{2^{\nu+2r+1}\lfloor r\,\Gamma(1+\nu+r)}-\phi'_\nu-\sum_0^\infty\frac{(-1)^p\,\Gamma(\frac{3}{2}+p)\,x^{\nu+2p+1}}{2^{\nu+2p+1}\lfloor p\,\Gamma\,(2+\nu+p)}$$

$$=-\phi'_\nu+\sum_0^\infty\frac{(-1)^r\,\Gamma(\frac{1}{2}+r)\,x^{\nu+2r+1}}{2^{\nu+2r+1}\lfloor r\,\Gamma(1+\nu+r)}\left(1-\frac{\frac{1}{2}+r}{1+\nu+r}\right)$$

Hence $\left(\frac{x}{2}-\frac{1}{x}\right)\phi_\nu(x)=\left(\nu+\frac{1}{2}\right)\phi_{\nu+1}-\phi'_\nu$ . . . . . (2.3)

As a particular case,

$$2\phi'_0=\phi_1-x\,\phi_0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.4)$$

Now, from (2.2) we have

$$\phi''_\nu=\phi'_{\nu-1}-\frac{\nu}{x}\phi'_\nu+\frac{\nu}{x^2}\phi_\nu.$$

Also, from (2.3),

$$\left(\frac{x}{2}-\frac{\nu-1}{x}\right)\phi_{\nu-1}=\left(\nu-\frac{1}{2}\right)\phi_\nu-\phi'_{\nu-1}.$$

Adding the last two equations we get

$$\phi''_\nu+\left(\frac{x}{2}-\frac{\nu-1}{x}\right)\phi_{\nu-1}=\left(\nu-\frac{1}{2}\right)\phi_\nu-\frac{\nu}{x}\phi'_\nu+\frac{\nu}{x^2}\phi_\nu$$

or, $\phi''_\nu+\left(\frac{x}{2}-\frac{\nu}{x}+\frac{1}{x}\right)\left(\phi'_\nu+\frac{\nu}{x}\phi_\nu\right)=\left(\nu-\frac{1}{2}+\frac{\nu}{x^2}\right)\phi_\nu-\frac{\nu}{x}\phi'_\nu$,

on using (2.2). Hence

$$\phi''_\nu+\left(\frac{x}{2}+\frac{1}{x}\right)\phi'_\nu+\left(\frac{1}{2}-\frac{1}{2}\nu-\frac{\nu^2}{x^2}\right)\phi_\nu=0 \quad . \quad . \quad . \quad (2.5)$$

This result could also be arrived at by starting with (1.1) and making use of the differential equation satisfied by the function ${}_1F_1$.

Other results that can be easily derived from the above formulae are:

$$\left(\frac{x^2}{2\nu}-1\right)\phi_{\nu-1}+\left(2-\frac{x^2}{2\nu}\right)\phi'_\nu=\left(\nu+\frac{1}{2}\right)\phi_{\nu+1} \quad . \quad . \quad . \quad (2.6)$$

$$\left(\frac{x}{2}-\frac{2\nu}{x}\right)\phi_\nu+\phi_{\nu-1}=\left(\nu+\frac{1}{2}\right)\phi_{\nu+1} \quad . \quad . \quad . \quad . \quad (2.7)$$

$$\phi''_\nu=\phi_{\nu-2}-\frac{2\nu-1}{x}\phi_{\nu-1}+\frac{\nu(\nu+1)}{x^2}\phi_\nu \quad . \quad . \quad . \quad . \quad (2.8)$$

$$\phi'''_\nu=\phi_{\nu-3}-\frac{3(\nu-1)}{x}\phi_{\nu-2}+\frac{3\nu^2}{x^2}\phi_{\nu-1}-\frac{\nu(\nu+1)(\nu+2)}{x^3}\phi_\nu \quad . \quad (2.9)$$

3. We have $\frac{d}{dx}\left(x^\nu\phi_\nu\right)=x^\nu\phi'_\nu+\nu x^{\nu-1}\phi_\nu$

$$=x^\nu\left(\phi_{\nu-1}-\frac{\nu}{x}\phi_\nu\right)+\nu x^{\nu-1}\phi_\nu$$

$$=x^\nu\,\phi_{\nu-1}$$

Thus $$\frac{d}{xdx}\left(x^{\nu}\,\phi_{\nu}\right)=x^{\nu-1}\,\phi_{\nu-1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.1)$$

Similarly, $$\left(\frac{d}{xdx}\right)^{m}\left(x^{n}\,\phi_{n}\right)=x^{n-m}\,\phi_{n-m.} \quad . \quad . \quad . \quad . \quad . \quad (3.2)$$

where m is $a+ve$ integer.

In the same way, we can prove that

$$\frac{d}{xdx}\left(x^{-\nu}\,\phi_{\nu}\right)=\left(\nu+\frac{1}{2}\right)x^{-\nu-1}\,\phi_{\nu+1}-\frac{1}{2}x^{-\nu}\,\phi_{\nu,} \quad . \quad . \quad . \quad (3.3)$$

$$\left(\frac{d}{xdx}\right)^{2}\left(x^{-\nu}\,\phi_{\nu}\right)=\left(\nu+\frac{1}{2}\right)\left(\nu+\frac{3}{2}\right)\phi_{\nu+2}$$
$$-\left(\nu+\frac{1}{2}\right)x^{-\nu-1}\,\phi_{\nu+1}+\frac{1}{4}x^{-\nu}\,\phi_{\nu} \quad . \quad (3.4)$$

4. $$\phi_{\nu}(x)=\sum_{0}^{\infty}\frac{(-1)^{r}\,\Gamma(\frac{1}{2}+r)x^{\nu+2r}}{2^{\nu+2r}\,\lfloor r\,\Gamma(1+\nu+r)}$$

$$=\sum_{0}^{\infty}\frac{(-1)^{r}\,.\,(\frac{1}{2}x)^{\nu}}{\Gamma(\frac{1}{2}+\nu)\,\lfloor r}\,.\,\frac{x^{2r}}{2^{2r}}\,.\,\frac{\Gamma(\frac{1}{2}+\nu)\,\Gamma(\frac{1}{2}+r)}{\Gamma(1+\nu+r)}$$

$$=\sum_{0}^{\infty}\frac{(-1)^{r}\,.\,(\frac{1}{2}x)^{\nu}}{\Gamma(\frac{1}{2}+\nu)\,\lfloor r}\,.\,\frac{x^{2r}}{2^{2r}}\int_{0}^{1}t^{\nu-\frac{1}{2}}\,(1-t)^{r-\frac{1}{2}}\,dt$$

$$=\frac{(\frac{1}{2}x)^{\nu}}{\Gamma(\frac{1}{2}+\nu)}\int_{0}^{1}t^{\nu-\frac{1}{2}}\sum_{0}^{\infty}\frac{(-1)^{r}\,x^{2r}}{2^{2r}\,\lfloor r}\,(1-t)^{r-\frac{1}{2}}\,dt,$$

a process easily justifiable Hence

$$\phi_{\nu}(x)=\frac{(\frac{1}{2}x)^{\nu}}{\Gamma(\nu+\frac{1}{2})}\int_{0}^{1}\frac{t^{\nu-\frac{1}{2}}}{\sqrt{1-t}}\;e^{-\frac{1}{4}x^{2}(1-t)}\;dt \quad . \quad . \quad . \quad . \quad (4.1)$$

$$=\frac{(\frac{1}{2}x)^{\nu}}{\Gamma(\nu+\frac{1}{2})}\int_{0}^{1}\frac{(1-u)^{\nu-\frac{1}{2}}}{\sqrt{u}}\;e^{-\frac{1}{4}x^{2}u}\;du \quad . \quad . \quad . \quad . \quad (4.2)$$

This result may also be thrown into the forms

$$\phi_{\nu}(2\sqrt{\omega})=\frac{\omega^{\frac{1}{2}\nu}}{\Gamma(\nu+\frac{1}{2})}\int_{0}^{1}\frac{t^{\nu-\frac{1}{2}}}{\sqrt{1-t}}\;e^{-\omega(1-t)}\;dt.$$

$$=\frac{\omega^{\frac{1}{2}\nu}}{\Gamma(\nu+\frac{1}{2})}\int_{0}^{1}\frac{(1-u)^{\nu-\frac{1}{2}}}{\sqrt{u}}\,e^{-\omega u}\;du.$$

Finally, (4.1) is equivalent to

$$\phi_\nu(x)=2\frac{(\frac{1}{2}x)^\nu}{\Gamma(\nu+\frac{1}{2})}\int_0^{\pi/2}\sin^{2\nu}\theta.\ e^{-\frac{1}{4}x^2\cos^2\theta}\ d\theta. \qquad (4.3)$$

5. Let us evaluate the integral

$$I=\int_0^\infty x^{p-1}e^{-ax^2}\phi_\nu(bx)\,dx \qquad (p>0,\ a>0)$$

$$=\int_0^\infty x^{p-1}\ e^{-ax^2}\sum_0^\infty\frac{(-1)^r\,\Gamma(\frac{1}{2}+r)\,(bx)^{\nu+2r}}{2^{\nu+2r}\lfloor r\ \Gamma(1+\nu+r)}\,dx$$

$$=\sum_0^\infty\frac{(-1)^r\,\Gamma(\frac{1}{2}+r)b^{\nu+2r}}{2^{\nu+2r}\lfloor r\,\Gamma(1+\nu+r)}\int_0^\infty e^{-ax^2}x^{p+\nu+2r-1}\,dx,$$

a process easy to justify. Hence

$$I=\sum_0^\infty\frac{(-1)^r\,\Gamma(\frac{1}{2}+r)\,\Gamma(\frac{1}{2}p+\frac{1}{2}\nu+r)b^{\nu+2r}}{2^{\nu+2r+1}\Gamma(1+\nu+r)\lfloor r\ .\ a^{\frac{1}{2}p+\frac{1}{2}\nu+r}}$$

$$=\frac{b^\nu}{2^{\nu+1}a^{\frac{1}{2}p+\frac{1}{2}\nu}}\sum_0^\infty\frac{(\frac{1}{2}p+\frac{1}{2}\nu,r)\,\Gamma(\frac{1}{2}p+\frac{1}{2}\nu)\sqrt{\pi}\,(\frac{1}{2},r)}{(\nu+1,r)\lfloor r\ \Gamma(\nu+1)}\left(-\frac{b^2}{4a}\right)^r$$

$$=\frac{b^\nu\,\Gamma(\frac{1}{2}p+\frac{1}{2}\nu)\sqrt{\pi}}{2^{\nu+1}\,a^{\frac{1}{2}p+\frac{1}{2}\nu}\Gamma(\nu+1)}\ F\left(\tfrac{1}{2},\tfrac{1}{2}p+\tfrac{1}{2}\nu;\ \nu+1;-\frac{b^2}{4a}\right) \qquad (5.1)$$

Particular cases

(*i*) $p=\nu+2$

$$\int_0^\infty x^{\nu+1}\ e^{-ax^2}\ \phi_\nu(bx)\,dx=\left(\frac{b}{2}\right)^\nu\frac{1}{a^{\nu+\frac{1}{2}}}\ \frac{1}{\sqrt{b^2+4a}}\qquad\left(\nu>-1\right) \qquad (5.2)$$

Further, putting $a=\frac{1}{4}b^2$, we get

$$\int_0^\infty x^{\nu+1}\ e^{-\frac{1}{4}b^2x^2}\phi_\nu(bx)\,dx=\frac{2^{\nu+\frac{1}{2}}}{b^{\nu+2}} \qquad (5.3)$$

In particular, when $b=2$,

$$\int_0^\infty x^{\nu+1}\ e^{-x^2}\ \phi_\nu(2x)\,dx=\frac{1}{2\sqrt{2}} \quad . \quad . \quad . \quad . \quad . \quad (5.4)$$

(i) $p=1$

$$\int_0^\infty e^{-ax^2}\ \phi_\nu(bx)\,dx = \frac{\pi b^\nu}{2^{2\nu+1}\ a^{\frac{1}{2}\nu+\frac{1}{2}}\ \Gamma(\frac{1}{2}\nu+1)}$$

$$\times\ \mathrm{F}\left((\tfrac{1}{2},\ \tfrac{1}{2}\nu+\tfrac{1}{2}\ ;\ \nu+1\ ;-\frac{b^2}{4a}\right) \quad . \quad . \quad . \quad . \quad . \quad (5.5)$$

Putting $a=\frac{1}{4}b^2$, we get

$$\int_0^\infty e^{-\frac{1}{4}b^2x^2}\ \phi_\nu(bx)\,dx = \frac{\pi}{2^2 b\ \Gamma(\frac{1}{2}\nu+1)}\ \mathrm{F}(\tfrac{1}{2},\ \tfrac{1}{2}\nu+\tfrac{1}{2}\ ;\ \nu+1\ ;-1)\ , \quad . \quad (5.6)$$

ON THE EXPANSIONS AND INFINITE INTEGRALS CONTAINING WHITTAKER'S M-FUNCTIONS

By D. P. Banerji

A. M. College, Mymensingh

Communicated by Professor A. C. Banerji

(Received on March 20, 1941)

The object of this paper is to consider certain new expansions and infinite integrals containing Whittaker's M-functions.

The generating function of Lagurre polynomials* is $\frac{e^{\frac{xt}{t-1}}}{(1-t)^{\alpha+1}} = \sum_0^\infty t^n \lfloor_n^\alpha (x)$

which is valid for $|t| < 1$.

Hence $\frac{e^{\frac{xt}{t-1}}}{(1-t)^{2\alpha+1}} = \sum_0^\alpha t^n \lfloor_n^{2\alpha} (x)$

Again we know† $\lfloor_r^{2m}(\pm z) = e^{\pm\frac{z}{2}} z^{-(m+\frac{1}{2})} \times$

$$\frac{\lceil 2m+r+1}{\lfloor r \ \lceil 2m+1}\ M^{(z)}_{\pm(\frac{1}{2}+m+r),\ m}$$

Hence $e^{\pm\frac{x(t+1)}{2(t-1)}} \frac{x^{\alpha+\frac{1}{2}}}{(1-t)^{2\alpha+1}} = \sum_0^\infty \frac{\lceil 2\alpha+n+1}{\lfloor n \ \lceil 2\alpha+1} \times$

$$M^{(x)}_{\pm(\frac{1}{2}+\alpha+n),\ \alpha}$$

$$\sum_0^\alpha \frac{\lceil \alpha+n+1}{\lfloor n \ \lceil 2\alpha+1} M^{(x+y)}_{\frac{1}{2}+\alpha+n,\ \alpha} = \frac{(x+y)^{\alpha+\frac{1}{2}} e^{\frac{(x+y)(t+1)}{2(t-1)}}}{(1-t)^{2\alpha+1}}$$

* E. Feldheim, "On Lagurre and Hermite Polynomials," *Quarterly Journal of Mathematics* (Oxford Series), Vol. II, No. 41, p. 26.

† A. Erdely's, "Infinite integrals involving Whittaker functions," *The Journals of Indian Mathematical Society*, Vol. III, No. 5, p. 177.

$$= (x+y)^{\alpha+\frac{1}{2}} \frac{e^{\frac{x(t+1)}{2(t-1)}}}{(1-t)^{2\alpha-2\beta}} \cdot \frac{e^{\frac{xy(t+1)}{2(t-1)}}}{(1-t)^{2\beta+1}}$$

$$= (x+y)^{\alpha+\frac{1}{2}} \sum_0^\infty t^\gamma \frac{\lceil 2\alpha-\beta+\gamma}{\lfloor\gamma \lceil 2\alpha-2\beta} x^{-(\alpha-\beta)} M^{(z)}_{\alpha-\beta+\gamma,\ \alpha-\beta-\frac{1}{2}}$$

$$\times \sum_0^\infty \frac{t^s \lceil 2\beta+s+1}{\lfloor s \lceil 2\beta+1} y^{-(\beta+\frac{1}{2})} M^{(y)}_{\frac{1}{2}+\beta+s,\ \beta}$$

Equating the co-efficients of t^n we have

$$M^{(x+y)}_{\frac{1}{2}+\alpha+n,\ \alpha} = \frac{\lfloor n \lceil 2\alpha+1}{\lceil 2\alpha+n+1} (x+y)^{\alpha+\frac{1}{2}} x^{-(\alpha-\beta)} y^{-(\beta+\frac{1}{2})} \times$$

$$\sum_{\gamma=0}^{n} \frac{\lceil \alpha-2\beta+n-\gamma \ \lceil 2\beta+\gamma}{\lfloor n-\gamma \ \lceil 2\alpha-2\beta \ \lfloor\gamma \ \lceil 2\beta+1} \cdot M^{(x)}_{\frac{1}{2}+\alpha-\beta,\ n-\gamma,\ \alpha,\ \beta-\frac{1}{2}} \times M^{(y)}_{\frac{1}{2}+\beta+\gamma,\ \beta}$$

Again $\sum_0^\infty t^n \lfloor^{2\alpha}_{n} (x+y) = \frac{e^{\frac{(x+y)t}{t-1}}}{(1-t)^{2\alpha+1}} = \sum_0^\infty \frac{(-y)^\gamma t^r e^{\frac{xt}{t-1}}}{\lfloor r \ (1-t)^{2\alpha+r+1}}$

$$= \sum_0^\infty \frac{(-y)^r t^r}{\lfloor r} \sum_0^\infty t^m \lfloor^{2\alpha+r}_{m} (x)$$

Hence equating the co-efficients of t^n we have

$$\lfloor^{2\alpha}_{n} (x+y) = \sum_{r=0}^{n} \lfloor^{2\alpha+r}_{n-r} (x) \frac{(-y)^r}{\lfloor\gamma}$$

Hence $M^{(x+y)}_{\frac{1}{2}+\alpha+n,\ \alpha} = (x+y)^{\alpha+\frac{1}{2}} e^{-\frac{y}{2}} \frac{\lceil 2\alpha+1 \ \lfloor n}{\lceil 2\alpha+n+1} \times$

$$\sum_{r=0}^{n} \frac{(-y)^r}{\lfloor\gamma} \frac{\lceil 2\alpha+1+n}{\lfloor n-r \ \lceil 2\alpha+r} x^{-\left(\alpha+\frac{r+1}{2}\right)} M^{(z)}_{\frac{1}{2}+\alpha+n-\frac{r}{2},\ \alpha+\frac{r}{2}}$$

$$\int_0^\infty e^{-ay} M^{(x+y)}_{\frac{1}{2}+\alpha+n,\alpha} J_m(by)\, dy$$

$$= \lceil 2\alpha+1 \ \lfloor n \sum_{r=0}^{n} \frac{(-1)^r x^{-\left(\alpha+\frac{r+1}{2}\right)}}{\lfloor r \ \lfloor n-r \ \lceil 2\alpha+\gamma} M^{(x)}_{\frac{1}{2}+\alpha+n-\frac{r}{2},\ \alpha+\frac{r}{2}} \times$$

$$\int_0^a e^{-(a+\frac{1}{2})y}\, y^r\, J_m(by)\, dy \,*$$

$$= \sqrt{2a+1}\, \lfloor n \sum_{r=0}^{n} \frac{(-1)^r\, x^{-(a+\frac{r+1}{2})}}{\lfloor r \lfloor n-r \sqrt{2a+r}} M^{(x)}_{\frac{1}{2}+a+n-r/2,\, a+r/2} \times$$

$$\frac{b^m}{2^m (a+\frac{1}{2})^{m+r+1}} \frac{\pi(m+r)}{\pi(m)} F\left\{ \frac{m+r+1}{2}, \frac{m+r+2}{2}, m+1, \frac{-b^2}{(a+\frac{1}{2})^2} \right\}$$

$$\int_0^\infty e^{y/2}\, y^{t-1}\, M^{(x+y)}_{\frac{1}{2}+a+n,\, a} (x+y)^{-(a+\frac{1}{2})}\, G_m(ay)\, dy \dagger$$

$$= \sqrt{2a+1}\, \lfloor n \sum_{r=0}^{n} \frac{(-1)^r\, x^{-(a+\frac{r+1}{2})}}{\lfloor r \lfloor n-r \sqrt{2a+r}} M^{(x)}_{\frac{1}{2}+a+n-r/2,\, a+r/2} \times$$

$$\frac{2^{l+r-2}}{a^{l+r}} e^{\frac{i(l+r-m)}{2}} \left\lfloor \frac{l+r-m}{2} \right\rfloor \left\lfloor \frac{l+r+m}{2} \right\rfloor$$

if $R(l \pm m) > 0$, $R(a) > 0$

$$\int_{-\infty}^{\infty} e^{-(y-ix)^2 + y/2}\, M^{(x+g)}_{\frac{1}{2}+a+n,\, a} (x+y)^{-(a+\frac{1}{2})}\, (2y)^p\, dy$$

$$= \sqrt{2a+1}\, \lfloor n \sum_{r=0}^{n} \frac{(-1)^r\, x^{-(a+\frac{r+1}{2})}}{2^r \lfloor r \lfloor n-r \sqrt{2a+r}} M^{(x)}_{\frac{1}{2}+a+n-r/2,\, a+r/2} \times$$

$$\int_{-\infty}^{\infty} e^{-(y-ix)^2} (2y)^{p+r} \ddagger$$

$$= \sqrt{2a+1}\, \lfloor n\, \sqrt{\pi} \sum_{r=0}^{n} (-1)^r\, x^{-(a+\frac{r+1}{2})}\, M^{(x)}_{\frac{1}{2}+a+n-r/2,\, a+r/2} \times$$

$$\frac{i^{p+r} H_{p+r}(x)}{x^r \lfloor r \lfloor n-r \sqrt{2a+r}}$$

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*Gray, "Bessel Functions," p. 76.

†Gray, l. c. p. 66. using formulae (10)

‡E. Feldheim l. c., p. 23.

AN ANOMALY IN THE ELASTIC BEHAVIOUR OF INDIA RUBBER

By A. N. Puri

Physics Department, Hindu College, Delhi

Communicated by Dr. D. S. Kothari

(Received on April 24, 1941)

SUMMARY

The ratio of statical and dynamical rigidity for a sample of India Rubber at different temperatures and for various loads is determined. It is found that the value of the ratio at a given temperature increases with the load while for a given load it decreases with the temperature.

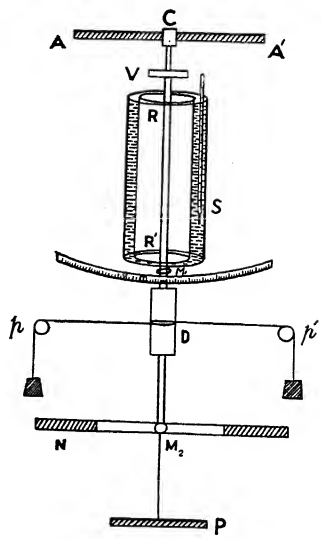
Introduction

The elastic properties of India Rubber have been studied by a number of investigators (Andrews, Deodhar and Kothari). The elastic modulii for India Rubber are much smaller than for metals and the periodic times in any vibration experiment are sufficiently large to be determined accurately. Therefore the study of elastic behaviour of India Rubber offers a good field of investigation in elucidating some interesting problems which it would be very difficult, if not impossible, to study in the case of metals. It was found by earlier investigators that the value of rigidity determined by the Vibration method was larger than that determined from Young's Modulus (E), calculated by the formula $n = \frac{E}{2(1+\sigma)}$ where σ is Poisson's ratio. To discuss the cause of this discrepancy I undertook a systematic study of this subject and the results were published in the proceedings of the National Academy, of Sciences, Volume 7th, Part I, 1937. I determined Young's Modulus and the rigidity of India Rubber, both statically and dynamically It was found that the dynamical value of Young's Modulus (E) is much larger than the statical value of E, and came to the conclusion that the discrepancy is due to the fact that the rigidity was measured by the dynamical method whereas in the relation $n = \frac{E}{2(1+\sigma)}$ the value of E was determined statically. It was also found that if we use for E the value determined dynamically, then the observed rigidity agrees within the limits of experimental error with the value calculated from the above relation. An immediate explanation that suggested itself was that the dynamical E corresponds to the adiabatic modulus and the

statical E to the isothermal one. The previous observations were taken at the ordinary temperature and with a view to study the effect of temperature on statical and dynamical rigidity the present investigation was undertaken by me.

Procedure

The apparatus is essentially a Maxwell needle and is very simple in construction. An iron bar AA′ is firmly fixed at its ends in a wall and in the middle of the bar there is a clamp C, in which is fixed a vice V which holds the ends of the India Rubber band RR′ firmly. The other end of the band is fixed to a brass cylinder D with an axle passing through its centre. To the lower end of the cylinder is screwed another iron rod which carries a Maxwell needle at its lower end. The needle is enclosed in a box with glass sides to avoid air draughts. The lower end of the needle carries a pan in which weights can be placed. At M_1 a small plane mirror is attached and the light from a lamp reflected by it is allowed to fall on a scale placed above the lamp in the horizontal position. Another mirror M_2 is fixed to the middle of the Maxwell needle and the light from another lamp reflected from it falls on another scale placed above the lamp. The rubber band is surrounded by a double-walled cylinder S provided with a thermometer. The cylinder can be filled with ice or water at any desired temperature and its outer surface is covered with cotton wool to prevent radiation. Two threads fixed to the end of the axle pass over two pulleys p and p′ and they carry equal weights. By this means a couple is applied to the end of the rubber tube which is twisted.



To start with the experiment, a load of 1 K. gram was placed in the pan and the cylinder was filled with ice.

Sufficient time was allowed to elapse before taking observations so that the temperature became constant. Then the period of vibration of the Maxwell needle with the solid tubes outside and the empty tubes inside was determined with a very sensitive stopwatch. Next the period of vibration with the solid tubes inside was determined. After this, the couple was applied to the end of the band and when the spot of light reflected from M_1 on the scale became stationary, its position was noted. Knowing the previous position of the spot, the deflection was calculated. Next keeping the load the same, the cylinder was filled with water at various temperatures and the experiment repeated In this way a set of readings at various temperatures were taken. In the same way observations were taken for various loads The distance of the mirror M_1 to the scale was measured with a metre stick. The tubes both solid and empty were weighed and the length of Maxwell needle determined. The results were recorded thus: —

OBSERVATIONS FOR 1 K. GRAM LOAD

Temperature		32°C
Period of oscillation with solid tubes outside, . .	T_1	28·94 sec.
„ „ „ inside, . .	T_2	19·6 sec.
Deflection, ...	x	43·5 cms.
Distance from M_1 to the scale	L	30·5 cms.
Difference between the masses of solid and empty tubes	M	227·0 gms.
Length of the Maxwell tube	L	47 6 cms.
Diameter of the cylinder carrying threads . . .	D	$\frac{95\cdot9}{22}$ cms.
Weights attached to each thread	M	1 gm. wt.

The ratio of the dynamical rigidity n_D to the statical rigidity n_S was calculated by the following formula:

$$\frac{\pi^2 L^2 M \times x}{(T_1^2 - T_2^2) \times 2L \times mg \times D}$$

$$\therefore \quad \frac{n_D}{n_S} = \frac{227}{980} \times \frac{(3\cdot1416)^2 \times 47\cdot6 \times 47\cdot6 \times 43\cdot5 \times 22}{48\cdot59 \times 9\cdot34 \times 2 \times 30\cdot5 \times 95\cdot9}$$

$$= 1\cdot87.$$

The results for various loads at different temperatures are given below :—

RESULTS

Load	Temp. $\frac{n_D}{n_S}$	Temp. $\frac{n_D}{n_S}$	Temp. $\frac{n_D}{n_S}$	Temp. $\frac{n_D}{n_S}$	Temp. $\frac{n_D}{n_S}$	Temp. $\frac{n_D}{n_S}$
0·25 K. gm.			0°C 1·722	30°C. 1·593	50°C. 1·397	75°C. 1·236
0·5 K. gm.			0°C. 1·865	26·4°C. 1·778	50 C 1·595	78·6°C. 1·396
1·0 K. gm.	− 20°C. 2·231	−10°C. 2·129	0°C. ·264	32°C. 1·87	56·4°C 1·683	60°C. 1·454
1·5 K. gm.			0°C 2·17	35°C. 1·90	53°C. 1·75	74°C. 1·482
2·0 K. gm.	− 18·5°C 2·437	−9·6°C. 2·297	1·5°C 2·264	32°C. 2·013	54°C. 1·725	78°C. 1·660
2·5 K. gm.			0°C. 2·37	35°C 2·101	59°C. 1·949	75°C. 1·86
3·0 K. gm.	−19°C. 2·677	−10°C. 2·585	0°C. 2·491	38·5°C 2·18	54·2°C 2·079	80·4°C. 1·924
3·5 K. gm.			0°C. 2·587	37·8°C 2·279	55·4°C 2·181	76·5°C. 2·013

Then the values of Young's Modulus and rigidity for different loads at different temperatures were determined by the ordinary method. The value of Poisson's ratio was also determined by applying the formula $2\sigma = \left(\frac{dv}{v}\cdot\frac{l}{dl} - 1\right)$, where dv denotes the change in volume and dl the change in length of the rubber tube. The value of dv was determined by filling the tube with water, suspending it from the vice with a glass tube in it and noting the change in the height of the water column and then multiplying it with the area of cross-section of the tube. The radius of the tube was measured with a microscope. From these values of σ the values of statical rigidity were calculated by applying the usual formula $n = \frac{E}{2(1+\sigma)}$

and the ratios calculated. The results for various loads at different temperatures are given below:

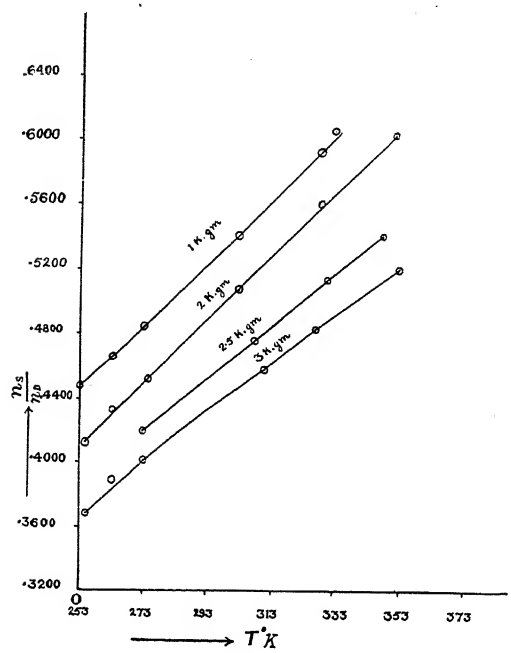
1. Load				1·0 K.gm.
Temp.	0°C.	35·°C.	54·0°C.	66·5°C.
σ	·43	·395	·42	·423
E	$161{\cdot}5\times10^5$	$160{\cdot}7\times10^5$	$131{\cdot}9\times10^5$	$88{\cdot}65\times10^5$
n_S	$56{\cdot}61\times10^5$	$57{\cdot}09\times10^5$	$46{\cdot}44\times10^5$	$31{\cdot}15\times10^5$
n_D	$107{\cdot}94\times10^5$	$92{\cdot}35\times10^5$	$68{\cdot}84\times10^5$	$59{\cdot}22\times10^5$
$\frac{n_D}{n_S}$	1·91	1·60	1·49	1·22

2. Load				1·5 K. gms.
Temp.	0°C.	36·5°C.	52·5°C.	74·5°C.
σ	·403	·415	·483	·502
E	$192{\cdot}3\times10^5$	$163{\cdot}6\times10^5$	$145{\cdot}8\times10^5$	$102{\cdot}1\times10^5$
n_S	66.65×10^5	$57{\cdot}8\times10^5$	$49{\cdot}27\times10^5$	$33{\cdot}9\times10^5$
n_D	$135{\cdot}75\times10^5$	$113{\cdot}61\times10^5$	$81{\cdot}2\times10^5$	$52{\cdot}26\times10^5$
$\frac{n_D}{n_S}$	2·04	1·97	1·65	1·63

3. Load				2·0 K. gms.
Temp.	0°C.	35·0°C.	53·8°C.	72·6°C.
σ	·412	·425	·453	·438
E	$217{\cdot}5\times10^5$	$198{\cdot}8\times10^5$	$168{\cdot}4\times10^5$	140.2×10^5
n_S	$77{\cdot}02\times10^5$	$68{\cdot}7\times10^5$	$58{\cdot}7\times10^5$	$48{\cdot}16\times10^5$
n_D	$165{\cdot}59\times10^5$	$137{\cdot}08\times10^5$	$105{\cdot}12\times10^5$	$82{\cdot}83\times10^5$
$\frac{n_D}{n_S}$	2·15	2·01	1·851	1·72

From the above observations it is clear that the ratio for a given load decreases with the temperature and at a given temperature increases with the load, thereby confirming the previous results.

Then graphs were drawn between the ratio $\frac{n_S}{n_D}$ and absolute temperature T for different loads and as is evident they were found to be straight lines, showing that $\frac{n_D}{n_S}$ is inversely proportional to the absolute temperature.



Conclusions

It is evident from the results that for a given load when the temperature is increased, the ratio of the dynamical rigidity to the statical rigidity decreases, but when for a given temperature the load is increased, the ratio increases. Thus when for a given load of 1 K.gm. the temperature increases from -20°C. to 60°C., the ratio decreases from 2·231 to 1·654, whereas for a load of 3 K.gms. for the same range of temperature, the ratio varies from 2·677 to 1·924. Further if the temperature be kept constant at 0°C. and the load increased from ·25 to 3·5 K.gms., the ratio increases from 1·722 to 2·587. This shows that the anomaly is very much marked at low temperatures and at high loads. At high temperatures and low loads the anomaly becomes very much less

My thanks are due to Dr D S Kothari, Head of the Physics Department, University of Delhi, for his interest in this work.

TIME PERIODICITIES IN COSMIC RADIATION

By P. S. Gill

Forman Christian College, Lahore

Communicated by Dr. Shri Ranjan

(Received on June 5, 1941)

In 1934, the Carnegie Institution undertook a world-wide study of cosmic rays. Seven precision meters to measure cosmic rays were constructed at the University of Chicago under the direction of Professor Arthur H. Compton, who designed these meters in collaboration with Drs. E. O. Wollan and R. D. Bennett. A detailed description of these meters is given in a previous paper[1]. Since most of the results of this publication are based on the data collected with five of these meters it would be quite apropos to give the essential features of these Model C meters in brief. The primary purpose of these meters is to secure continuous records of the variations of cosmic-ray intensity. Thus one can study the intensity variation of cosmic-rays (*a*) with respect to position, such as a function of latitude or as a function of altitude, (*b*) with respect to time such as sidereal and solar diurnal changes, annual, half-yearly and 27-day changes.

The ionization chamber consists of a steel bomb of 19·3 liters volume The relatively large size of the ionization chamber minimizes the statistical errors introduced by the finite number of rays. The number of rays measured per unit time depend inversely upon the area of cross-section of the chamber. Each of these chambers is filled with very pure argon at a pressure of 50 atmospheres except the one in Teoloyucan, Mexico, in which the pressure is 40 atmospheres. The shielding of each meter is equivalent to 12 cm. of pure lead, which is sufficient to stop all showers and shower-producing radiation.

A change in the position of the electrometer needle as registered on a photographic film must be due to one or more of the following processes: (1) Accidental deflections, (2) Time variations in the cosmic-ray intensity, (3) statistical fluctuations of the ionization, and (4) cosmic-ray bursts. Such instrumental failures as a loose electrical contact may make the position of the needle erratic. The resulting deflections should, however, always be positive if they are caused by sudden ionization, whereas such instrumental difficulties, which are rare, introduce equally frequent deflections in the positive and negative directions, and are readily recognizable. While (2) causes only slow variations in the position of the electrometer

needle, (3) and (4) give, from time to time, sudden changes easily distinguishable from the other type of variations. It is, however, important to establish exact criteria for distinguishing bursts from statistical fluctuations. Bennett, Brown and Rahmel[2] carried out calculations of this kind for a Carnegie Model C. cosmic-ray meter and obtained the following results :–

At Chicago a statistical fluctuation corresponding 0·5 mm. deflection of the electrometer needle is found to occur, on the average, once every 42·2 hours, and for 0·75 mm. deflection, once every 18,000 hours. Actually observed were 6—8 bursts between 0·5 and 0·75 mm. deflection per 42·2 hour period, so only bursts less than 0·5 mm. should be omitted

Time variation of cosmic-ray intensity :—

Before any study of time variation of cosmic-ray intensity can be made, a barometric correction has to be applied. The changes in the barometric pressure at sea level, that is, changes in the thickness of the atmospheric layer through which the rays must come before they reach the earth, cause the intensity to change in the opposite direction by about 2% for each centimeter change of barometric pressure. It is not a simple matter to apply the necessary corrections in a satisfactory manner.

The periodic variations following the solar day, the sidereal day, the annual period, the 6-month period and the 27-day period, are well known. Of these, the variations following the solar day have been established by Hess and his collaborators,[3] Forbush[4] and others[5]. The maximum of intensity occurs near noon and minimum around midnight. Julian Thompson,[6] by analyzing the data collected with a Model C meter placed on the R. M. S. Aorangi travelling between Vancouver and Sydney, determined the solar diurnal effect at different latitudes and found that the amplitude (·2%) of the first harmonic is the same at all latitudes and agrees well with that indicated by the data of Hess. All of these observers reported the 24-hour period and made no mention of a 12-hour period which at Teoloyucan (Mexico) appears to be more important than the former The author carried through the calculations for a solar diurnal effect with the data collected from February 1937 to February 1938 at Teoloyucan (Mexico). It is interesting to note that the 12-hour period at the above-mentioned place is even more prominent than the 24-hour period. The amplitudes and the phases of the first and second harmonics are as follows :—

Solar Diurnal Effect			
1st Harmonic	Phase	2nd Harmonic	Phase
·028	$10{\cdot}2^h$	·072	$4{\cdot}8^h$
Sidereal Diurnal Effect			
·058	18^h	·052	$4{\cdot}6^h$

The amplitudes are given in per cent of the total. Mrs. A T. Monk has carried out the calculations for the 1st and 2nd harmonics using the data collected over a

period of three years and by applying the dial method she shows the true nature of the 12-hour period. These results will be published elsewhere in the near future.

Because of its great theoretical interest we began to test the predictions of Compton and Getting[7] based on their galactic rotation theory. According to one of their predictions there should exist a sidereal diurnal effect with a maximum of intensity at 19 hours. Professor A. H. Compton and the author[8] analyzed the data collected at Teoloyucan (Mexico) and that published by Illing, Schonland and his collaborators, and Forbush by the dial method. A weighted mean of all the data then collected indicated an amplitude of the sidereal time variation which is only a small fraction of that predicted by Compton and Getting. These results showed an indication of the existence of a real second harmonic, that is, a 12-hour sidereal period.

According to the theory of the galactic rotation effect, if the cosmic rays do not share the rotational motion of the galaxy, the intensity in the Northern Hemisphere should be roughly 0·5 per cent greater than in the Southern Hemisphere.

The results[9] of 26 trips on the R M S Aorangi from Vancouver, British Columbia to Sydney, Australia, and on the S S. Talune to Hobart, Tasmania, extended over a period of about 32 months, was to show very little difference between the two Hemispheres. On both sides of the equator the intensity was found to be greater in the colder than in the warmer months, as is also shown by more recent measurements made with the same meter by Gast and Loughridge[10] between geomagnetic latitudes of 53° 33′N and 61° 36′N. This observation led to the determination of an atmospheric temperature coefficient of the intensity of cosmic rays. This coefficient was found to vary from about −0·25% per degree C above latitude of 40° to about −0·05% at 25° latitude, a result predicted by Blackett from his disintegrating meson theory of the temperature effect.

When suitable corrections are applied to the observed intensity for this temperature effect and the familiar barometer effect, it is found that no detectable variation with latitude occurs at distances farther than 40° from the magnetic equator. At these higher latitudes the difference in the cosmic-ray ionization between the Northern and Southern Hemispheres is ± about 0·1 per cent.

This result is inconsistent with the predicted difference of 0·5% magnitude, but is consistent with the smallness of the observed sidereal time variations. This may mean either that the motion of the sun with the rotation of the galaxy is much slower than has generally been supposed, or that the cosmic rays share the rotational motion of the galaxy. The former view is supported by certain recent astronomical studies by Camm,[11] and the latter view is strongly argued by Alfven.[12]

The author[13] published a study of annual, half-yearly as well as 27-day changes in cosmic-ray intensity made from the data collected with four Model C cosmic-ray meters situated at widely different stations. A special attention was paid to the variations following the solar rotation.

When the daily mean ionization as observed at the different stations was plotted against time, there occasionally appeared variations having a period of roughly a month which could be followed through several cycles and then gradually became confused with other variations This suggested the search for a variation of a quasi-periodic type such as has been reported by Hess[14] and Graziadei.[15] The method of analysis is fully explained by A. T. Monk and A H. Compton[16] who further studied the 27-day period.

The length of the period appears to be 27·9 days and has an amplitude of 0·18%. The two prominent astronomical periods of approximately this length are (1) the sidereal month, of 27·32 days, and (2) the period of the sun's rotation relative to the earth.[17] This period varies from about 26 days at the equator to 32 days at 80°, with a mean value given as about 27·1 days. The lack of persistence of the quasi-periodic changes that we are discussing suggests that they should not be associated with something so definite as the revolution of the moon. On the other hand, this characteristic fits well with the view that they may be associated with some surface activity on the sun such as sun-spots. The known correlation between the appearance of sun-spots and terrestial magnetic disturbances lends support to this suggestion. However, it is too early to assign definite causes.

The author wishes to express his sincere appreciation to Prof. Arthur H. Compton for continued advice and encouragement. The author wishes to thank Mrs. Ardis T. Monk for help in calculations.

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NITROGEN FIXATION UNDER STERILE CONDITIONS

By N. R. Dhar and E. V. Shesharcharyulu

Indian Institute of Soil Science, Allahabad

(Received on January 28, 1941)

SUMMARY

(1) With numerous carbohydrates it has been found that even under completely sterile conditions the nitrogen fixed per gram of carbon oxidised in light in quartz-vessels with soil is 12·2 milligrams; in glass vessels in light it is 10·7 milligrams, whilst in the dark it is approximately 4·5 milligrams per gram of carbon oxidised. The order of these fixations under sterile conditions is practically the same as obtained in unsterilised soils. It appears that the efficiency of nitrogen fixation whether the soil contains Azotobacter or is sterile is practically the same.

(2) With oxides like ZnO, Al_2O_3, Fe_2O_3, Ni_2O_3, CoO, MnO_2 etc. used as surface instead of soil and glucose as the energy material the nitrogen fixation per gram of carbon oxidised is of the order of 15 to 18 milligrams in light under completely sterile conditions, whilst in the dark it is 8—11 milligrams. Under unsterile conditions the fixation in light varies from 30 - 46 milligrams and in the dark from 15 to 24 milligrams per gram of carbon oxidised. The difference in nitrogen fixation under sterile and unsterile conditions with oxides may be due chiefly to the deficiency of aeration under sterile conditions.

(3) The fertility of the Indian soils as well as in other countries, from the nitrogen view-point appears to have originated, and is being maintained chiefly by the fixation of atmospheric nitrogen in the soil aided by sunlight through the oxidation of energy materials like celluloses, fats, carbohydrates formed by photosynthesis and added in the form of plant residues. It appears that much more nitrogen is fixed in these natural processes by light absorption than the nitrogen fixed by the industrial processes. The chief source of nitrogen in soils of all countries seems to be the atmospheric nitrogen fixed mainly by a surface reaction, aided by absorption of sunlight.

It has been advocated that nitrogen fixation in soils is entirely a bacterial process although the amount of nitrogen fixed under non-symbiotic conditions is considered to be negligible as will be seen from the following quotations :—

"Laboratory investigations in humid climates suffer from the difficulty that the soils already contain so much nitrogen that small changes are difficult to measure accurately, and there are losses of nitrogen which counterbalance any fixation. Investigation would be easier in some of the soils, very poor in nitrogen found in hot, arid conditions. Rigid incontestable proof could be furnished only by a demonstrated gain in nitrogen effected by Azotobacter, all other possibilities being ruled out This proof is not yet forthcoming." (Russell, "Soil Conditions and Plant Growth," 193', page 342.)

"It is difficult to obtain clear evidence showing how much nitrogen is fixed in soils in natural conditions, by free-living nitrogen-fixing organisms. Wherever

a gain in nitrogen has been recorded in natural conditions in humid climates there have also been leguminous plant growing to which it might be attributed." (Russell, "Soil Conditions and Plant Growth," 1932, page 389)

"In view of the fact that the energy added to the soil is not directly available to the nitrogen-fixing bacteria, that small amounts of available nitrogen are always present in the soil, and the error in the laboratory determination by the kjeldahl method is greater than the possible amount of nitrogen fixed by non-symbiotic bacteria, we are still unable to decide the question definitely." (Waksman, "Principles of Soil Microbiology," 1931, pp. 514-515.)

"Wide use is being made in systems of agriculture of the bacteria, which work with legumes, but the nitrogen fixing power of those which work outside the plant is as yet not utilised extensively by man, since the methods of controlling them are not well understood." (Miller, "The Soil and Its Management," 1924, page 203.)

For a number of years we have been carrying on extensive research work on this phenomenon and we have established that nitrogen fixation can take place in soils when supplied with energy materials, like carbohydrates, celluloses, cowdung, pentosans, fats, leaves, hay, etc., and the amount of nitrogen fixation in light is always greater than in the dark.

Our results show that in light the nitrogen fixation is very much greater than in the dark and it is quite clear that in nitrogen fixation in soils sunlight is utilised as in photosynthesis in plants. In Nature large quantities of energy materials are added to the soil chiefly in the form of cellulose and the oxidation of this energy material leads to an enormous amount of nitrogen fixation, which is aided by sunlight. This is certainly the chief source of the nitrogen supply to the plants. This phenomenon appears to be in importance next to photosynthesis in plants. In artificial light exactly similar results can be obtained.

From our experiments carried on in the dark at different temperatures with glucose as energy material it is observed that the optimum temperature for nitrogen fixation with a value 7·76 mgs. per gram carbon oxidised in the dark is 35° as against about 28° (26°–30°) observed in temperate countries. Above and below this temperature the fixation is less. At 11° and 60° the fixation is nil. The nitrogen fixed in the exposed soil, the temperature of which varied from 40° to 44°, is much greater than that in the incubated soils and has the value 13·1 mgs. per gram of carbon oxidized in light. Under comparable conditions, the nitrogen fixed per gram of carbon oxidised when the soil is exposed to sunlight is always greater than the nitrogen fixed per gram of carbon oxidised at various temperatures, whereas the Azotobacter numbers in the exposed soil are much less when compared to those in the soils incubated at temperatures 25°, 30°, 35°, 40° and 45° and kept in the dark. In sunlight the nitrogen fixed is much greater than that obtained at the optimum temperature 35°. This definitely proves

that the increase of temperature is not responsible for the greater nitrogen fixation observed in light but is mainly due to the photooxidation of the energy-rich substances and energy added by light absorption. Therefore photochemical fixation of atmospheric nitrogen is very important and light is at least as essential as bacteria in the process of fixation of nitrogen in tropical soils. We have also observed that the bacteria in the system exposed to light is enfeebled in comparison with those kept in dark with the same energy material.

Influence of Sunlight on Nitrogen Fixation with Pure Cultures of Azotobacter.

Media used.

2% Mannitol.

0·2 gm. $K_2H\ PO_4$ in 1000 c.c.

10 gms. $CaCO_3$ in 1000 c.c.

Tap-water 1000 c.c.

500 c.c. of the medium were taken in 2 litres pyrex flasks. 1 c.c. of the same inoculum was used in all the cases. Experiments were done in duplicates. One set was exposed and the other set covered with black cloth and kept side by side with the exposed flasks.

Experiments were started on 1-11-1938, and analysed on 3-1-1939.

Total Nitrogen in 100 c.c.

Exposed	1	0·0125	Mean = 11·75 milligrams of nitrogen in 100 c.c.
	2	0·011	
Covered	1	0·017	Mean = 18·5 milligrams of nitrogen in 100 c.c.
	2	0·02	

Hence in light, there is less fixation of nitrogen than in the dark under the conditions prevailing in culture experiments.

Recently we have carried on experiments under completely sterile conditions and in such cases also we have obtained fixation of nitrogen not only with sterile soils but with surfaces like those of ZnO, CoO, Fe_2O_3, Al_2O_3, MnO_2, etc.

In the following experiments 50 gms. soil were taken to which 1 gram glucose with small amounts of water was added in glass or quartz vessels

These were carefully sterilized and either exposed to light directly with plugs of cotton wool or covered with black cloth to exclude light and kept side by side with the exposed vessels. In every case, it was tested by the plating method to ascertain that there was no bacterial contamination during the course of the experiments.

Fixation with Unsterile Oxides.—In these experiments 50 grams of chemically pure oxide containing no nitrogen were mixed with 1 gram glucose. Experiments were started on 25-2-1940 and analysed on 20-4-1940.

	Light.			*Dark.*		
	Total nitrogen.	Total carbon.	Total bacteria in millions per gram of the dry mixture.	Total nitrogen.	Total carbon.	Total bacteria in millions.
MnO_2	0·015 %	0·3125 %	1·96	0·0058%	0·4285 %	2·92
CuO	0·0088 „	0·5092 „	0·62	0·0027 „	0·6498 „	0·88
CoO	0·0187 „	0·3035 „	1·02	0·0085 „	0·4012 „	3·20
Ni_2O_3	0·02335„	0·2968 „	0·98	0·010 „	0·3862 „	2·98

Nitrogen fixed per gram of carbon oxidised

	Light.	*Dark.*
MnO_2	35·78 mgm.	15·61 mgm.
CuO	30·26 „	17·97 „
CoO	37·66 „	21·31 „
Ni_2O_3	46·7 „	24·16 „

Nitrogen fixation with oxides and carbonates of metals under sterile conditions (one litre Pyrex flasks used) in *light* with the addition of glucose:—

In the following experiments 25 grams of oxide were taken to which 0·5 grams glucose added. Started on 13-2-1940 and analysed on 1-7-1940.

	Light.		
	Total nitrogen.	Total carbon.	N. fixed per gram of carbon oxidised.
ZnO	0·0048 %	0·4826 %	15·12 mgm.
Al_2O_3	0·0038 „	0·5348 „	14·33 „
Fe_2O_3	0·0056 „	0·5016 „	18·76 „
Ni_2O_3	0·0056 „	0·4972 „	18·49 „
CoO	0·0048 „	0·5124 „	16·66 „
CuO	0·0020 „	0·628 „	14·43 „
MnO_2	0·0048 „	0·4624 „	14·21 „
$CuCO_3$	nil	0·7084 „	nil
$MnCO_3$	„	0·6928 „	„
$CoCO_3$	„	0·7084 „	„

Dark

Analysed on 1-9-1940

ZnO	0·0017	0·5892	8·06
Al_2O_3	0·0017	0·6084	7·87
Fe_2O_3	0·0020	0·6172	10·94
Ni_2O_3	0·0020	0·6108	10·57
CoO	0·0020	0·6084	10·43
CuO	...	0·7124	...
MnO_2	0·0017	0·6084	8·87

	Total Carbon.	Total Nitrogen.		
Cowdung	8·812%	0·35 %		
Soil	0·5263	0·0516	9·8	Total bacteria in millions per gram of dry soil.
Soil and cowdung	0·7082	0·0583		gms,
For 100 gms. of the material carbon added was			0·1762	„
Total nitrogen added			0·0072	„

Unsterile

Experiments with cowdung started on 12-7-1940 and analysed on 15-9-1940. 2 % cowdung was added. 25 gms. of oxide and 50 gms. soil were taken.

	Light.			*Dark.*		
	Total nitrogen.	Total carbon.	Total bacteria.	Total nitrogen.	Total carbon.	Total bacteria.
Soil	0·0616 %	0·5742 %	16·82	0·06 %	0·5852 %	30·6
ZnO	0·0106 „	0·0198 „	2·8	0·0086 „	0·0524 „	5·2
Al_2O_3	0·01 „	0·0218 „	3·2	0·0086 „	0·00524„	6·8
Fe_2O_3	0·0108 „	0·0198 „	2·6	0·0086 „	0·0498 „	5·95
Ni_2O_3	0·0108 „	0·0204 „	1·98	0·0086 „	0·0498 „	4·25
CoO	0·0108 „	0·0198 „	2·01	0·0086 „	0·5106 „	6·86
MnO_2	0·0086 „	0·0486 „	1·65	0·0076 „	0·0878 „	3·8

Nitrogen fixed per gram of carbon oxidised.

	Light	*Dark.*
Soil	24·62 mgms.	13·8 mgms.
ZnO	23·01 „	12·8 „
Al_2O_3	19·4 „	12·8 „
Fe_2O_3	24·2 „	12·6 „
Ni_2O_3	24·3 „	12·6 „
CoO	24·2 „	12·7 „
MnO_2	23·01 „	12·5 „
CuO	12·5 „	6·7 „

Sterile

Oxides of metals +0·5 gms glucose + 0·5 gm. V_2O_5. ·25 gms oxide were taken. Started on 18-7-1940, and analysed on 2-12-1940.

Light.

	Total nitrogen %	Total carbon %	Nitrogen fixed per gram of carbon oxidised.
$ZnO + V_2O_5$	0·0056	0·4628	16·6
$Fe_2O_3 + V_2O_5$	0·0056	0·4934	18·5
$Al_2O_3 + V_2O_5$	0·0048	0·5086	16·4
$Ni_2O_3 + V_2O_5$	0·0056	0·4826	17·6
$MnO_2 + V_2O_5$	0·0048	0·4702	14·8

Corresponding dark experiments were carried on and analysed on 28-1-1941.

$ZnO + V_2O_5$	0·002	0·5762	8·47
$Fe_2O_3 + V_2O_5$	0·002	0·5884	9·4
$Al_2O_3 + V_2O_5$	0·0017	0·5912	8·1
$Ni_2O_3 + V_2O_5$	0·002	0·5884	9·4
$MnO_2 + V_2O_5$	0·0017	0·6004	8·5

It is highly interesting to note that the nitrogen fixed per gram of carbon oxidised under completely sterile conditions in soils in quartz flasks is 12·2 mgs. in light and 4·8 mgs. in the dark with carbohydrates as energy materials.

Similarly, from the experiments carried on in Pyrex glass vessels which cuts off more light, especially the ultra-violet, than quartz, the mean nitrogen fixation is

10·74 mgs. per gram. of carbon oxidised under perfectly sterile conditions in light in soil whilst in the dark the fixation is 4·5 mgs. The order of these fixations under sterile conditions is practically the same as obtained without sterilisation in soils.

It appears, therefore, that the efficiency of nitrogen fixation, whether the soil contains Azotobacter or is sterile, is practically the same. In other words, the means by which the energy material is oxidised and the energy is made available does not affect the efficiency of the process.

When the energy materials are added to the soil, they are oxidised with the liberation of energy, and this energy is utilised in nitrogen fixation under ordinary conditions. In natural conditions the energy materials are oxidised on the soil surface and also oxidised by the living organisms. But under sterile conditions, the micro-organisms are destroyed and the phenomenon of oxidation is a non-biological surface reaction. But the efficiency of the two processes, as far as the nitrogen fixation is concerned, is of the same order in soils. Hence we are forced to conclude that nitrogen fixation can take place in as efficient a manner as possible in soils as well as in surfaces in the same way as in natural conditions in presence of living organisms.

With the carbonates of copper, manganese and cobalt no nitrogen fixation was observed under the experimental conditions recorded possibly due to their slight decomposition forming carbon dioxide which might have displaced the oxygen necessary for nitrogen fixation.

Our results show that the nitrogen fixed per gram of carbon oxidised using either carbohydrates or fats as energy material and oxide surfaces instead of soil is very much greater than the amount of nitrogen fixed with soils both in sterile and unsterile conditions. With soils containing approximately 0·04 to 0·05% total nitrogen, the amount of nitrogen fixed per gram of carbon oxidised with carbohydrates and fats is of the order of 10 to 12 milligrams in light and 4 to 6 mgs. in dark both in sterile and unsterile conditions. On the other hand, with surfaces of oxides like Al_2O_3, ZnO, Fe_2O_3, MnO_2 containing no nitrogen at all, the nitrogen fixed per gram of carbon oxidised both with carbohydrates and fats is of the order of 30 mgs. in light and 10 to 12 mgs. in dark under unsterile conditions. This interesting relation is caused by the fact that the nitrogen fixation is opposed by the phenomenon of loss of nitrogenous compound present in the system or formed therein undergoing oxidation, because the unstable substance ammonium nitrite is formed in the process of oxidation of the nitrogenous compounds produced by fixation or present in soil and hence nitrogen loss is facilitated. In soils, there is already a certain amount of combined nitrogen, *i.e.*, to the extent of 0·04 to 0·05% in tropical soils and hence the loss of nitrogen is more marked than when oxide surfaces are used containing no nitrogen. Apparently the efficiency of the process of nitrogen fixation becomes much

better in presence of oxide surfaces than in soils containing nitrogen. These observations are of fundamental importance in explaining the formation of fertile soils and the growth of plant life on the surface of the earth from original rocks. It is well known that soils are formed only when geological deposits or mineral materials are brought under the influence of living matter and of the products of their metabolism and decay. The primary source of soil organic matter and nitrogen is the vegetation. The geological deposits, *i.e.*, the parent materials of soil do not contain any organic matter, but can contain inorganic nitrogen in the form of nitrates or of ammonia in very small quantities. The nitrate can under the influence of light and moisture and seeds, form the first set of vegetable or plant life, the nitrogen need of which is met from the inorganic nitrogen, *i.e.*, nitrates or ammonia originally present in small quantities in rocks. The carbohydrates and the cellulosic materials or other energy compounds formed in photosynthesis undergo decomposition in course of time and are oxidised causing nitrogen fixation in this process, and thus the store of nitrogen in the system is increased; and this in its turn leads to a more abundant growth of vegetation and this process goes on in which the carbon and nitrogen status of the system is improved leading to the formation of fertile soil. Hence from small amounts of combined nitrogen present in geological minerals the formation of fertile soil is a possibility. As the original mineral is poor in nitrogenous compound the nitrogen fixation is greatly enhanced in the beginning but with the storing up of nitrogen the efficiency falls off and thus the nitrogen and carbon status of the soil reaches a maximum limit depending on the climate of the region.

This process of nitrogen fixation is perhaps a non-biological one especially in the beginning at any rate chiefly caused by the oxidation of the energy materials formed in photosynthesis under the influence of surface and light. It is difficult to assume that nitrogen fixing organisms, like Azotobacter and Clostridium which are not always present even in soils, should exist in the rock deposits which are the parent materials of the soil.

It is clear, therefore, that under normal conditions the carbon and nitrogen status of a soil and hence the fertility of a land and its crop production ultimately depends on this process of nitrogen fixation which, in the beginning at any rate, certainly is a non-biological surface process aided by light, and is greatly enhanced, as has been explained above, because of the presence of very small amounts of combined nitrogen present in geological rocks.

The experimental results recorded in this paper showing that nitrogen fixation is possible with chemically pure surfaces like Fe_2O_3, ZnO, Al_2O_3, MnO_2 etc. and that the efficiency of this process is greater with oxides than in soil are of considerable importance. For nitrogen fixation neither soils nor bacteria are absolutely necessary. What really seems indispensable is a suitable surface where oxygen, nitrogen and

energy-material are properly adsorbed and are in intimate contact in such a way that the oxidation of the energy material is possible.

Moreover, with soils there is greater chance of the formation of a compact mass specially on sterilisation and hence the chances of aeration are less in soil than in the oxides causing a decrease in the amount of nitrogen fixation in soils. It is well known that aeration plays an important part in nitrogen fixation. The difference in nitrogen fixation under sterile and unsterile conditions with oxides may be chiefly due to the deficiency of aeration under sterile conditions. Our results on the influence of light on nitrogen fixation in soil have been confirmed in different laboratories.

In a recent communication S. N. Bhattacharya and Shri Ranjan (Proceedings of National Academy of Sciences, 1940, **10,** Section B, p. 65) have reported that there is more nitrogen fixation in light when soil and molasses are exposed to light under completely sterile or unsterile conditions. Similar results were obtained at Brisbane (Australia) by Dr. Kerr and by M. Sulaiman at Dacca (J. Indian Chem. Soc, 1941, **18,** p. 40).

DO NON-LEGUMINOUS PLANTS APPROPRIATE ATMOSPHERIC NITROGEN?

By N. D. Vyas

Imperial Agricultural Research Institute, New Delhi

Communicated by Rao Bahadur B. Viswa Nath

(Received on February 24, 1941)

SUMMARY

That the plants require nitrogen for their metabolism is an axiomatic truth and that some of the plants like legumes, possess the power of utilising atmospheric nitrogen, through the agency of certain micro-organisms, is also a universally recognized fact but whether non-leguminous plants are endowed with the same quality or not is yet a very disputed question. Therefore, in order to fathom out the truth a series of experiments were carried out at the Imperial Agricultural Research Institute. The results are presented in the paper.

The investigations were carried out with maize, a cereal, under field conditions as well as under controlled conditions in the laboratory.

Six years' trial under field conditions revealed that in four years there was a significant evidence of appropriation of atmospheric nitrogen by maize while in two years there were losses of insignificant amounts of original nitrogen.

Pot culture experiments with soil or with sand+nitrogen-free-nutrient solution presented positive evidence of appropriation of atmospheric nitrogen. Similar was the case with water culture experiments.

Whether such fixation was through bacterial agency, as is the case with legumes or whether it was independent in itself was further examined by special bacteriological tests, described in the paper. It has been found that such appropriation in the case of maize is not directly connected with bacterial association as is the case with legumes The experimental evidence reveals that such power is possessed by the plant itself. Indirectly, its root secretions do play a part in stimulating nitrogen-fixing micro organisms of soils. It has been found that in the presence of maize root secretions the amount of nitrogen fixed by soil organisms in Ashby's mannite solution was 15 to 20% more than in the control.

It is an established fact that the plants belonging to the Natural Order Leguminosæ, appropriate atmospheric nitrogen through symbiosis with root nodule organisms but whether the non-leguminous plants are gifted with the power of utilising atmospheric nitrogen, either by themselve or through bacterial agency is yet a disputed question. The problem was, therefore, taken up for investigation.

Literature on the subject presented contradictory views. Some of the early workers, Boussingault,[2] Lawes, Gilbert and Pugh,[11] Mene,[15] Liebig[12] definitely opined that the non-leguminous plants did not fix atmospheric nitrogen.

Some of their contemporaries as well as later workers found positive evidence, but they differed in their opinion on the mechanism of fixation of nitrogen. Priestley,[17] Ville[25], Cloez and Gratiolet[5], Chlebodrow[4], Jamieson[9], Frank[7], Moor and Webster [16], Wan[28], Lipman and Taylor[13,14], Allison and Hoover[1], and De[6] considered that the plants themselves possessed the power of appropriating atmospheric nitrogen. On the other hand Schneider[20], Joshi[10], Greaves[8], Caron[3], Starkey[22], Vyas[27], Viswa Nath[26], Sahashrabudhe[18,19], Sen[21], Truffaut and Bezsonoff[23,24] found that directly or indirecty bacterial association was essential in the fixation of nitrogen by non-leguminous plants. In some cases specific or modified organisms, as reported by Schneider, Joshi, Caron, Truffaut and Bezsonoff and Sen, performed the function of fixing nitrogen in association with non-leguminous plants, while in the opinion of the rest the general nitrogen fixing organisms of the soil were found to receive benefit either by secretions of roots or through the crop residues.

Thus it will be seen that there are three schools of thought. Those belonging to the first school do not recognise the nitrogen-fixing power of non-leguminous plants, those of the second accept that the power of fixing nitrogen is possessed by the plants themselves while those of the third are of opinion that the task of appropriating nitrogen is possessed by general or specific organisms which work in symbiosis, with non-leguminous plants.

Experimental

In a preliminary trial with 8 plots in 1929-30 it was found that on an average 151 lbs. of Nitrogen per acre was appropriated by maize. Later on systematic experiments were laid out in 1930-31. Observations were continued up to 1934-35 and would have continued further were it not for the transfer of the Imperial Agricultural Research Institute from Pusa to New Delhi.

16 Plots were laid out for maize, which was sown every year in June and harvested by the end of September. During *Rabi* season other crops were taken as shown below:—

Treatment.	*Kharif.*	*Rabi.*
A	Maize	Barley.
B	„	Kerao (Pisum arvense).
C	„	Barley and Kerao mixed
D	„	Barley and Kerao in alternate years.

The results obtained with different crops are presented in the following table :—

**Table showing Lbs of nitrogen or lost per acre-foot of soil by growing different crops.*

CROP	YEARS.		
	1930-31	1931-32	1932-33
Maize (Av. of 16 plots).	107·19 ± 24·4	−9·38 ± 15·41	−48·31 ± 24·13
Barley(„ „ 4 „)	86·75 ± 44·02	−29·50 ± 28·47	−32·25 ± 15·68
Kerao („ „ 4 „)	105·00 ± 61·67	124·75 ± 15·03	29·50 ± 25·02
Barley and Kerao (Av. of 4 plots).	70·75 ± 52·61	99·75 ± 21·06	99·25 ± 22·11

1933-34	1934-35	Average gain. Lbs.	Remarks.
54·13 ± 15·13	96·06 ± 16·17	40	Significant gain in 3 years
24·00 ± 18·74	13·50 ± 21·77	12	Significant loss in 1 year.
94·75 ± 26·20	33·50 ± 42·25	78	Significant gain in 2 years
160·50 ± 34·76	51·75 ± 13·58	96	Significant gain in 4 years

Nitrogen was determined by wet digestion† in an acre-foot of soil both at the time of sowing the crops as well as at harvest. Nitrogen absorbed by the crops was also determined.

From the above figures it will be seen that on an average of 5 years mixed crop of Barley and Kerao (a cereal and a legume) fixed 96 lbs. of N. per acre, followed by Kerao, Maize and Barley, the respective amounts of nitrogen fixed being 78, 40 and 12 lbs.

The above results were confirmed at Delhi with Delhi soil. The experiments were conducted in pot cultures. The idea in using pots instead of plots was to insure greater accuracy in sampling soils than that could be accomplished under field conditions. The usual technique of filling up pots was followed. Field soil was collected to a depth of 1 ft. and used for the above experiment.

The first two series were conducted with one kilogram of soil and the next two with four kilograms. To start with, the soil was saturated with one-third its saturation capacity but later on, after a few days, the moisture content was raised to half the saturation.

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*Nitrogen absorbed by the crops was added to that found in the soil.

†Jour. Agri. Sci. 15, **15** : 454—459.

Number of replications in the first two series were six while in the last two they were eight. The results are shown below :—

Table showing the amount of nitrogen fixed per kilogram of soil.

Period.	Gain or loss of nitrogen found in the soil, bearing the crop as well as in the crop less that of the sown seeds.	Gain or loss of nitrogen in fallow soil.	Net gain or loss by cropping with maize.
	Mgm.	Mgm.	Mgm.
1st series 26-11-37 to 7-2-38.	+ 21·45	+ 4·18	+ 17·27
2nd series 18-7-38 to 7-10-38.	+ 26·92	−18·33	+ 45·25
3rd series 24-11-38 to 20-4-39.	+ 10·50	− 7·5	+ 18·00
4th series 4-7-39 to 22-4-39.	+ 17·87	− 5·0	+ 22·87

These results at Delhi with Delhi soil stand in conformity with those at Pusa with Pusa soil. It will be further seen that when maize was grown during normal seasons it fixed more nitrogen than that in off seasons. In normal seasons it fixed 45·25 and 22·87 mgm. of nitrogen per kilogram of soil against 17·27 and 18·00 mgm. of nitrogen respectively in off seasons. In terms of percentage the gains over original soil nitrogen were 6·2%, 7·3%, 4·2%, and 8·3% in the cropped soil against 1·4% gain and 6%, 3%, and 1·8 % losses in the fallow soil.

The Mechanism of the Fixation of Nitrogen by Maize

Both the field and the pot culture experiments have shown the nitrogen-fixing power of maize but it is not known how this fixation takes place. Is it through bacterial agency or through the plant itself? To elucidate this point further experiments were conducted.

So far as the fixation of nitrogen is concerned bacterial association could be of three kinds, *viz.*—

1. Through root secretions, which might act as stimulant or energy-supplying material to general nitrogen-fixing flora of soil and thus encourage nitrogen fixation in soil.

2. A specific organism may remain dormant inside the seed and become active when the embryo turns itself into plant.

3. It may be that soil possesses specific organism, like root nodule bacteria which work in symbiosis with non-leguminous plants forming nodules or they get activated in close proximity of roots and act like rhizobia in the thick-walled lignified root hair.

Of these three possibilities the first was examined by cultural tests. To cultures of soil organisms growing in Ashby's solution, maize root washings* were added and their effect observed The results are shown below. The figures of the second and third series are the averages of four flasks and those of the fourth series are of six flasks.

Stimulating effect of maize root washings on the fixation of nitrogen in Ashby's solution by soil organisms.

Nitrogen fixed over the controls per 100 cc. medium.

Treatment.	2nd set 29-9-31 to 22-10-31.		3rd set 6-7-31 to 27-7-32.		4th set 9-9-32 to 30-9-32.	
	Mgm.	%	Mgm.	%	Mgm.	%
Candle filtered, Washings.	3·1	23·96	2·025	15·70	2·15	15·56
Washings sterilised at 120°C. for 30 minutes.	1·1	8·15	1·15	8·91	1·33	9·62

These figures show that the maize root washings when filtered through candle increased the amount of nitrogen fixed over the controls by 23·96% to 15·56%. When heat was applied as a sterilising agent the stimulating property was reduced. The nitrogen fixed in the latter case was increased only by 8·15% to 9·62% over the controls.

2. The second possibility of the presence of specific organisms was examined by germinating sterilised seeds, asceptically crushing them and then transferring the crushed material to agar slants or liquid medium. Examination of the slant or the medium did not reveal the presence of any organism, thereby showing that the possibility of the presence of any organism inside the seed does not exist.

3. As regards the third possibility of root infection by soil organisms, the microscopic examination failed to reveal the formation of even minute nodules on the roots or the presence of any organism inside the roots.

The conclusion arrived at by these experiments was that the general nitrogen-fixing flora of the soil are stimulated by maize root washings, but whether the plants

* 40 Maize plants were dug out, their roots were washed free of the adhering earth and then placed in 200 c.c. distilled water for 24 hours. This water was then filtered either through filter paper or filter candle as necessary. 5 c.c. of these washings were added at an interval of 3 days till six washings were added.

themselves are endowed with the power of fixing nitrogen by themselves yet remained to be examined.

For this sand and water culture experiments were carried out.

Sand Culture Series

Four to five kilograms of ignited and thoroughly washed sand with nutrient-medium used by Thornton and Hugh* were placed in glazed pots. Four maize seeds of equal weights and known nitrogen content were sown. After a certain period of growth the plants were cut and nitrogen was determined.

Nitrogen fixed by 4 Maize Plants over that of the seeds sown.

(average of 5 to 6 pots).

	Mgm.	Per cent.
2nd series 25.11.37 to 29.3.38	19·63	163·9
3rd series 1.7.38 to 27.9.38	11·10	100·0
4th series 13.12.38 to 25.4.39	11·37	79·0

These results show that the plants too possess the power of appropriating the atmospheric nitrogen.

The next question, to be settled, was to find out whether the plants absorbed free or combined nitrogen. For this, water culture experiments were conducted in a special type of apparatus in which air washed free of combined nitrogen was continually bubbled through the culture solution. This bubbling enabled aeration of the culture solution which is essential for success in water culture experiments. The plants were grown in enclosed vessels in which air washed free of combined nitrogen was being drawn continuously by means of water pump. Two plants were grown in each set. The results are shown below.

* J. Agri. Sci. 26: 173.

Nitrogen fixed by two maize plants, when grown in atmosphere, free of combined nitrogen, over their original nitrogen.

	Jar No.	Mgm.	Per cent.
2nd series			
10.12.38 to 11.1.39	1	3·9	48·15
	2	3·5	43·21
3rd series			
16.1.39 to 14.3.39	1	2·2	28·20
	2	2·8	35·89
	3	5·4	69·23
	4	1·8	23·08
	5	7·9	101·29
4th series			
8.10.39 to 24.1.40	1	4·0	50·63
	2	4·1	15·90

From the above results it will be seen that the amount of nitrogen of the seedling at start was increased by 23·08% to 101·29%. Since these experiments were conducted in atmosphere free of combined nitrogen it can be safely concluded that maize plants themselves are capable of appropriating the free atmospheric nitrogen.

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ON A NEW TREMATODE, *DIPLOZOON INDICUM* N. SP., FROM A FRESH-WATER FISH *BARBUS* (*PUNTIUS*) *SARANA* (HAM.)

By J. Dayal

Zoology Department, University of Lucknow

(Received on July 16, 1941)

In January (1940) while collecting helminth parasites from local fishes I discovered an immature specimen of *Diplozoon* attached to the gills of *Barbus* (*Puntius*) *sarana* (Ham.), from river Gomti. Since then about 200 fish have been examined during the course of the year, and about 20% of the fish were found infected with *Diplozoon*. The maximum number of specimens got from a fish was four, but ordinarily two specimens were found in each fish. Mature and gravid forms could only be found during the summer season, from March to July. Immature specimens could be found throughout the year. A large number of immature, mature and gravid forms were collected. To my knowledge this is the first time that a *Diplozoon* has been collected or reported from India.

The specimens were narcotised in water to which a small quantity of alcohol was added. They were then fixed with either in hot corrosive or in Bouin's fluid. Specimens treated with hot corrosive gave the best results. Transverse and longitudinal sections were also cut to verify the observations made on whole mounts. Ehrilich's acid haematoxylin and Eosin were used for staining.

Historical.—Our knowledge of the genus *Diplozoon* is based on two species only, *Diplozoon paradoxum* Nordmann (1832) from Europe, and *Diplozoon nipponicum* Goto (1891) from Japan. Zeller (1872), (1888), and Goto (1891) gave detailed accounts of the anatomy of *D. paradoxum* and *D. nipponicum* respectively, and also a description of the mode of union of the two individuals in the form of a cross

Diplozoon indicum N. Sp.

Diplozoon indicum is found attached by means of its posterior suckers to the gills of the fish, and is very similar to the other two known forms. The two individuals are united together in the form of a cross: the union of the two taking place behind the fore end of the posterior third of the body. The two uniting individuals are generally not of the same size, and it has already been observed that there is a notch and a twist at the place of crossing in consequence of the fact that one grasps with its ventral sucker the dorsal papilla of the other, with the result that

when a specimen is killed under pressure of a cover-glass the anterior and posterior halves of the same individual present to view the opposite sides of the body, *i.e.*, the anterior half presenting the dorsal if the posterior half shows the ventral side, and *vice versa*.

For purposes of description we may speak of the part in front of the place of union as the anterior and that behind the union as the posterior.

The following table gives the length of the two individuals united together, and the relative length of the anterior and the posterior portions of the body.

	Animal whose anterior portion is on the left side.	Animal whose anterior portion is on the right side.
1.	Total length ... ... 6 mm.	6·3 mm.
	Length of anterior portion ... 4 mm.	4·3 mm.
	Length of posterior portion ... 2 mm.	2·0 mm.
2.	Total length ... ... 7·5 mm.	7·6 mm.
	Length of anterior portion ... 5·3 mm.	5·4 mm.
	Length of posterior portion ... 2·2 mm.	2·2 mm.
3.	Total length ... ... 7·7 mm.	7·8 mm.
	Length of anterior portion ... 5·5 mm.	5·6 mm.
	Length of posterior portion ... 2·2 mm.	2·2 mm.
4.	Total length ... . 9·3 mm.	9·6 mm.
	Length of anterior portion ... 6·5 mm.	6·7 mm
	Length of posterior portion ... 2·8 mm.	2·9 mm.

The animals resemble the gill rays of the fish both in shape and colour. Their looping movements were observed in water in the living condition. The posterior portion of the body of both the animals is fixed to the bottom of the dish by means of posterior suckers, while the anterior portion of the body of both the animals is extended forwards and bent downwards in the form of an inverted U, and the two animals fix themselves to the bottom of the dish by their anterior suckers, the posterior suckers then relax and the whole body is drawn forwards by the contraction of the longitudinal muscles of the body. This process is repeated.

The length of the worms vary from 3—10 mm. The anterior portion of the body is leaf-like and is dorso-ventrally flattened. The greatest breadth is in front of the place of union of the two individuals, behind the place of union the body is constricted and is elliptical or semicircular in transverse section. In the region of the posterior suckers the body is dorso-ventrally flattened and more or less rectangular in shape.

In a worm measuring 6·3 mm. in length the anterior portion of the body is 4·30 mm. long, while the posterior portion of the body is 2 mm. long. The greatest breadth in front of the place of union is 0·8 mm. (The greatest breadth in front of the place of union varies from 0·5—0·9 mm.) In the region of the pharynx the breadth is 0·5 mm. (In the region of the pharynx the breadth varies from 0·3—0·6 mm.).

The organs of attachment.—A pair of anterior suckers are situated ventrally, one sucker lies on each side of the mouth. They are round or oval cup-shaped bodies with the concavity directed towards the ventral side The cavity of the suckers is connected through a groove with the mouth, and the suckers not only attach the animal firmly to the blood capillaries of the host but probably also help it in sucking the blood. Figure 3, a transverse section of the animal passing through the suckers and the mouth, shows the connection between the cavity of the suckers and the mouth. The suckers are 0·075 mm. in diameter. (The size of the suckers varies from 0·05—0·09 mm. in diameter.)

In the posterior region of the body are present four pairs of suckers, four suckers being placed laterally on either side of the body. Each posterior sucker is in the form of a bag with its mouth directed ventrally, and the line of its greatest breadth is placed transversely to the long axis of the body. It is lined both externally and internally by thick cuticle. The anterior and the posterior walls of the suckers are thick, due to the presence of bundles of elastic fibres, while the lateral walls are thin and consist of cuticular membrane. In figure 4A, a longitudinal horizontal section through one of the posterior suckers, the thick anterior and the posterior walls are seen connected by cuticular membrane. In figure 4B, a vertical longitudinal section through one of the posterior suckers, the thick anterior and the posterior walls are continuous at the bottom of the bag. The entire structure is supported by five chitinous rods (Figs. 2, 4A and 4B),—a hollow U-shaped median piece (MC) supporting the bag medially, and two pairs of curved hook-shaped pieces (AC and PC), a pair each supporting the anterior and the posterior walls. The paired rods are embedded in their respective walls and are hollow and somewhat triangular in transverse section (Fig. 4A, AC and PC). The rods of the anterior wall are articulated at their bases, each with the median piece (MC) embedded in the substance of the wall, while the rods of the posterior wall are articulated with each other. The anterior and the posterior rods in all cases break up into regular pieces on the

least pressure. All the suckers are not of equal size, the anterior sucker is the largest while those that follow are smaller than the one preceding, the last pair being the smallest. The first pair or the anterior pair of suckers is 0·17 mm. long by 0·38 mm. wide. The second pair of suckers is 0·16 mm. long by 0·37 mm. wide. Third pair of suckers is 0·14 mm. long by 0·34 mm. wide. The fourth or the last pair of suckers is 0·11 mm. long by 0·27 mm. wide The size of the suckers varies in different individuals but the anterior sucker is always the largest and the last the smallest.

In *D. paradoxum* and *D. nipponicum* the anterior pair of suckers is smaller than the next two, the last pair being the smallest.

A small pair of hooks, 0·03 mm. long is present in the posterior region of the body on the dorsal side.

Alimentary canal.—The mouth is a triangular opening on the ventral side at the anterior end of the body. On either side of the mouth lies a cup-shaped sucker, already described. The mouth opens into a prepharynx about 0·05 mm. long, which leads into a small muscular pharynx 0·05 mm. in diameter. The pharynx opens into a long tubular intestine, which extends from the pharynx to the level of the second posterior sucker. The intestine gives out a large number of dichotomously branched caeca on either side anterior to the place of union of the two individuals. The diverticula, which are not symmetrically arranged branch once or twice. Behind the place of union the intestine runs upto the ovary where it branches into two caeca which run on the dorsal side of the ovary. Behind the testis the two caeca unite to form a simple tube, which runs upto the middle or hind end of the second posterior sucker.

In *D. paradoxum* the intestine runs as a single tube, without branching, behind the place of union of the two individuals, and it gives out lateral caeca posterior to testis.

In *D. nipponicum* the intestine branches into two caeca behind the place of union of the two individuals. Posterior to the testis the two caeca unite and end in a rounded enlargement in the middle, a little anterior to the first pair of posterior suckers.

The male reproductive organs:—The testis lies in an oval sac, about 0·25 mm long by 0·19 mm. wide. It is situated at a distance of 0·86 mm. from the posterior end of the body. (The size of the sac varies from 0·20—0·40 mm. in length by 0·12—0·24 mm. in breadth.) The testis is oval in shape and is 0·23 mm. long by 0·15 mm. wide. (The size of the testis varies from 0·20—0·37 mm. in length by 0·12—0·20 mm. in breadth.) The vas deferens arises from the anterior end of the testis and runs forward as a distinct tube on one side of the uterus. Anteriorly it comes to lie on the dorsal side of the uterus and acquires a connection with the vitelline duct of the other individual at the place of union.

In *D. paradoxum* the testis is lobed and rounded or oval in shape. It lies between the first pair of posterior suckers. In *D. nipponicum* the testis is lobed and lies midway between the crossing of the individuals and the posterior margin of the body.

The female reproductive organs :—The ovary is in the form of a long band which bends twice on itself thus forming an inverted overlapping double U. It begins as a knob-like enlargement at the anterior end of the testis and extends up to the point of union of the two individuals. The oviduct arises between the two limbs of the ovary in the middle, about 0·35 mm. anterior to testis. The oviduct continues forward as the uterus receiving the vitelline duct at its place of origin. The uterus is a ciliated tube which runs forward along with vas deferens to open on the ventral side near the place of union of the two individuals. During its course it presents an enlargement in which an egg is present, and round which are present a large number of shell gland cells.

The vitelline glands consist of a large number of round or oval follicles filling nearly the whole of the space between the pharynx and the place of union of the two individuals. The common vitelline duct runs backward on the ventral side of the intestine, and opens into the uterus near its place of origin. The vitelline duct near the place of union with the uterus gives out a duct, the vitello-intestinal duct, which runs forward as a coiled tube and opens into the intestine.

Only one large egg with a long coiled filament is present in an individual. The eggs are oval, operculated, and with a thick yellowish-brown shell. They measure 0·22—0·24 mm. in length by 0·08—0·10 mm. in breadth, excluding filament which is very long and coiled. The eggs contain a large amount of yolk and the germplasm is more or less in the middle of the egg, about 0·03—0·04 mm. in diameter. The shell of the egg is about 0·007 mm. thick.

The distinguishing characters of the new form may be summarised as follows :—

1. The union of the two individuals takes place behind the fore end of the posterior third of the body.

2. A pair of anterior suckers, one on each side of the mouth.

3. Four pairs of posterior suckers, the anterior pair of suckers is the largest, while those that follow are smaller than the preceding one, the last pair is the smallest.

4. Mouth a triangular opening on the ventral side, prepharynx and pharynx present, intestine tubular and gives out dichotomously branched caeca anterior to the place of union of the two individuals, behind the place of union the intestine branches in two caeca which unite again posterior to testis. Behind the testis the intestine extends as a simple tube upto the posterior end of the second hind sucker.

5. Testis round or oval and lies in a sac anterior to the first pair of posterior suckers.

6. Ovary in the form of a long band which bends twice on itself thus forming an inverted overlapping double U.

7. Eggs large, operculated, with a long coiled filament and a thick shell, they contain a large amount of yolk and the germ-plasm is limited in the center of the egg.

Remarks:—The new form, *D. indicum*, differs from the other two known species, *D paradoxum* and *D. nipponicum*, in the position of the union of the two individuals, in the comparative size of the posterior suckers, in the structure and extent of the intestine, in the position and shape of the ovary and testis, and in the size of the eggs. These differences are enough to allocate the form to a new species, *D. indicum*.

My thanks are due to Prof. K. N. Bahl for the literature and the facilities given to carry on the work.

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Explanation of Plate

Fig. 1. *Diplozoon indicum*, entire view of the two individuals fixed under pressure of a cover glass. The vitelline glands have not been shown on the right side. Genital organs not completely shown.

Fig. 2A. *Diplozoon indicum*, enlarged view of the posterior region of the body with a diagrammatic representation of the genital organs and the posterior suckers.

Fig. 2B. *Diplozoon indicum*, egg highly magnified.

Fig. 3. *Diplozoon indicum*, T. S. in the region of the oral suckers and the mouth showing the groove connecting the mouth and the cavity of the oral suckers.

Fig. 4A. *D. indicum*, a longitudinal horizontal section through one of the posterior suckers,

Fig. 4B. *D. indicum*, a sagittal section through one of the posterior suckers.

Abbreviations used in the Figures

A.C., Anterior chitinous rod; *A.W.*, Anterior wall of posterior sucker; *D.*, Dorsal view; *eg.*, Egg; *f.*, Filament; *g. p.*, Genital pore; *G.*, Germ-plasm; *int.*, Intestine; *int. c*, Intestinal caeca; *Mc.*, Median chitinous rod; *m. o.*, Mouth opening; *N*, Nucleus; *o. s*, Oral sucker; *ov.*, Ovary; *P.C.*, Po terior chitinous rod; *ph.*, pharynx; *p. ph.*, prepharynx; *p s.*, Posterior sucker; *P.W.*, Posterior wall of posterior sucker; *t.*, Testis; *ut.*, Uterus; *vd.*, Vas deferens; *vit.*, Vitelline glands; *vit. d.*, Vitelline duct; *V.*, Ventral view; *y.*, Yolk.

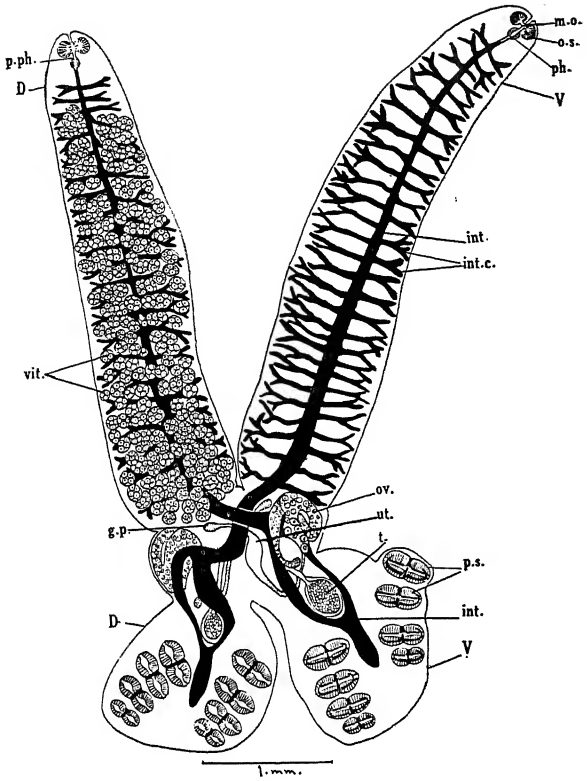


Fig. 1

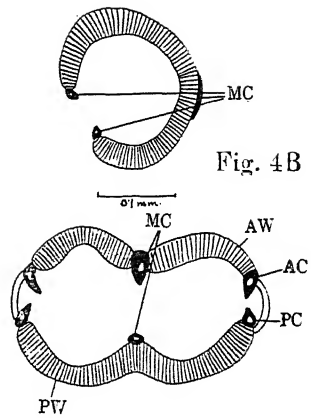


Fig. 4B

Fig. 4A

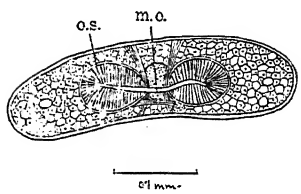


Fig. 3

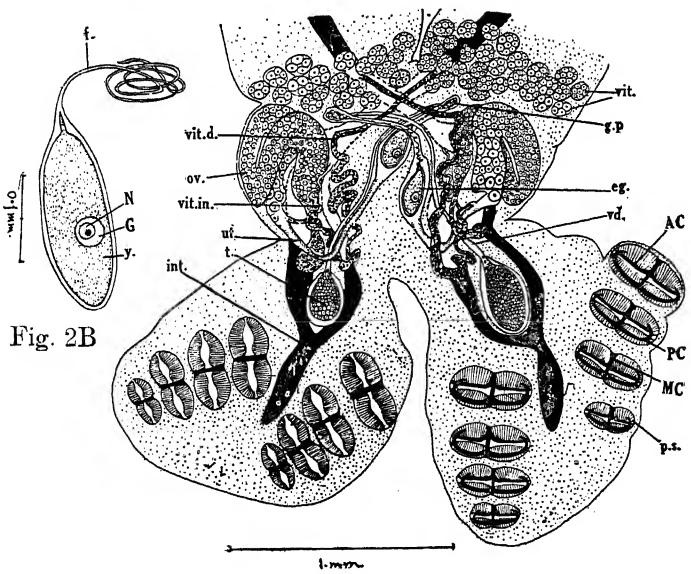


Fig. 2B

Fig. 2A

OBSERVATIONS ON A NEW AMOEBA, *DOBELLINA RAYI* N. SP., FROM *VARANUS MONITOR* LINN.

By P. L. Misra

Zoology Department, University of Lucknow.

Communicated by Professor K. N. Bahl

(Received on July 21, 1941)

SUMMARY

(i) A detailed morphological study has been made of a new amoeba, *Dobellina rayi* n. sp., found in the gut of *Varanus monitor*.

(ii) Amoeba belonging to the genus *Dobellina* has been recorded from a vertebrate host for the first time and named *D. rayi* which is the second species of this new genus.

(iii) The incidence of infection is 59 per cent.

(iv) Further observations on the cultivation of this amoeba and its effects upon the host in experimental infections will, I hope, be communicated in the near future.

Introduction

During my studies on the parasitic protozoa of *Varanus monitor*, I have come across an amoeba which shows a close resemblance to *Dobellina mesnili* described by Bishop and Tate (1939) from the dipterous larvae of *Trichocera haemalis* Meig. (the common "winter gnat") of Europe. The previous work on amoebic infection of reptiles in India is that by Knowles and Das Gupta (1930) from an Indian turtle, *Trionyx gangeticus*. These authors have not named their amoeba and have asserted that it has a close resemblance both to *Entamoeba testudinis* Hartmann (1910), and *E. barreti* Hegner and Taliaferro (1924). However, fixed and stained smears of the contents of the gut of *Varanus monitor* revealed that both *Entamoeba* and *Dobellina* were of frequent occurrence, of which the *Entamoeba* showed a very close resemblance to *E. invadens* Rodhain (1934), which has been shown by Ratcliffe and Geiman (1938) as the causative agent of gastro-enteritis in snakes and lizards of America.

While previously *Dobellina* has been recorded from an invertebrate host, I am describing the morphology of a new species of *Dobellina* from a vertebrate host, *i.e.*, *Varanus*. It is interesting to note that this amoeba is the second of its kind to be recorded under the genus *Dobellina* Bishop and Tate, and first to be described from a vertebrate host. Whether this new amoeba is pathogenic to its host will be considered in a later communication, as further work is in progress.

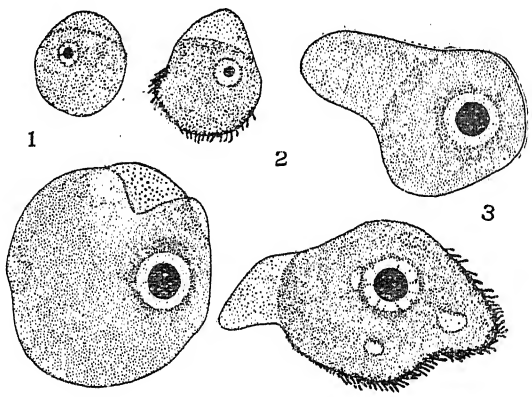
Material and Methods

Live specimens of *Varanus monitor* were obtained through the supplier of the laboratory animals to this department. The incidence of infection proved to be approximately 59 per cent from an examination of 27 individuals out of which 16 proved to be infected.

Observations on living amoebae were made in normal saline solution mixed with the gut contents of the host. Permanent preparations were made by fixing the smears in hot Schaudinn's fluid (acetic acid 5 per cent) for 12 to 15 minutes and staining with iron-alum haematoxylin. Pieces of gut were fixed in Gilson's mixture, Schaudinn's fluid and alcoholic Bouin, sectioned at 4 to 6 microns and stained with Delafield's haematoxylin or Heidenhain's iron-alum haematoxylin.

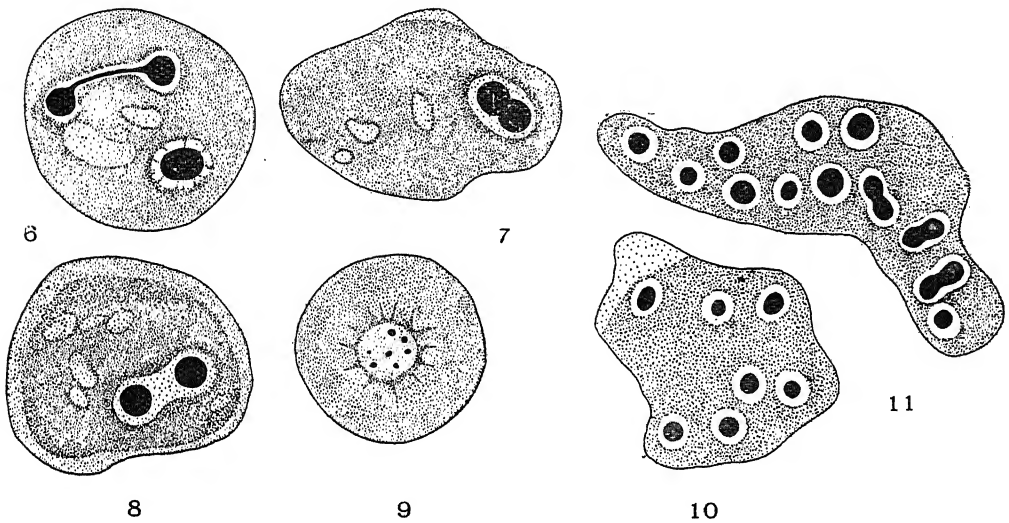
Morphology of Dobellina rayi N. Sp.

A vaselined cover-glass preparation of the gut-contents of the host diluted with normal saline showed that the amoebae were moving actively and could survive for as many as 12 hours in that medium. A broad, blunt pseudopodium consisting only of ectoplasm (figs. 1—5) is thrust out anteriorly and drags the animal forwards. But a prolonged examination of live



specimens showed that the pseudopodium in some of them assumed a dome-shaped contour and at times two pseudopodia could be seen protruding from one end of each organism. The endoplasm is totally devoid of chromatoid inclusions, but is charged with refringent granules and shows a rapid streaming movement. In certain specimens (figs. 2, 5) it could be noted that bacteria and other extraneous particles remained attached to the body of the organism indicating the adhesive nature of the protoplasm. The nucleus is not very conspicuous, though it can be distinguished as a translucent area in living specimens. Food vacuoles are absent and nutrition,

presumably, takes place by osmosis. Contractile vacuoles are also absent as in other parasitic amoebae. Fixed and stained preparations show a thin ectoplasmic layer and a granular endoplasm showing no vacuolization particularly in young forms, although slight vacuolization sets in with the growth of the trophozoites (figs. 5—8). In preparations stained with iron-alum haematoxylin the nucleus is found to consist of a central, spherical, and siderophilic karyosome separated from the nuclear membrane by a clear colourless halo. In some individuals very fine strands are seen to radiate from the karyosome to the nuclear membrane (figs. 1, 5, 6), while in others

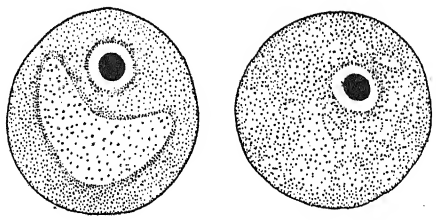


the karyosome resolves into 4 to 9 granules which probably represent an early stage in nuclear division (fig. 9).

The trophozoites measure 7μ—21μ, the average size being 9·92μ The nucleus is spherical in shape and is usually eccentric in position. It measures 4·2μ—5·6μ, the average size being 4·6μ. The Karyosome measures 1·8μ—2·8μ, the average size being 2·3μ. It may be noted that the maximum size of *D. rayi* (21μ) is smaller than that of *D. mesnili* (3·6μ × 3·6μ —25μ × 15μ) but its nucleus and karyosome are comparatively larger than those of the latter (N. 2·5μ—3μ; K. 1·2μ—1·5μ).

Cysts:—Uninucleate forms with vacuolated cytoplasm are not rare and represent the precystic stage (figs. 12, 13). Cysts with 2 to 8 nuclei (figs. 14—17) were very common, but often supernucleate cysts (fig. 18) containing 16 nuclei were also observed The wall of the cyst is thin and delicate. The cytoplasm when compared with that of the cysts of *D. mesnili* appears to be less vacuolated. Chromatoids are entirely absent from the cysts. The nuclei are smaller than those usually found in the trophozoites. Cysts measure 9μ—15μ in diameter and in this respect also differ from *D. mesnili* in which the cysts have been recorded to measure 8μ—11μ.

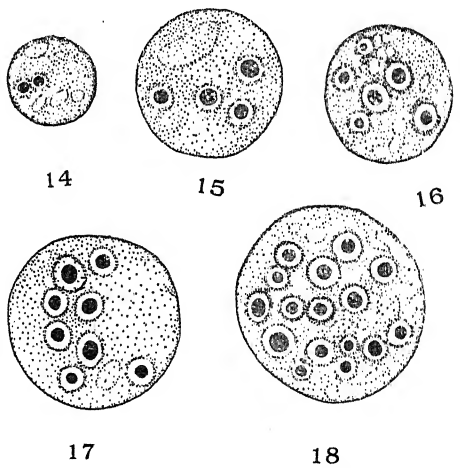
Unusually large supernucleate cysts measuring 18μ – 21μ in diameter and containing about 16 to 32 nuclei were also encountered.



12 13

Systematic Position.

Adhesive nature of the protoplasm, its differentiation into ectoplasm, and endoplasm, the latter being charged with refringent granules, presence of a broad hyaline pseudopodium formed of ectoplasm only, presence of a large central karyosome surrounded by an achromatic nuclear membrane, and the absence of chromatoids,



14 15 16

17 18

glycogen, food and contractile vacuoles are features which determine the position of this amœba under the genus *Dobellina* Bishop and Tate, 1939. The respective sizes of the trophozoites, the nucleus and the cysts, as mentioned above, clearly indicate that it is specifically different from *Dobellina mesnili* Bishop and Tate. It may be noted that the multinucleate trophozoites (figs. 10, 11) with more than four nuclei were encountered in lesser numbers in this species than in *D. mesnili*. Whether this is characteristic of *Dobellina* in a vertebrate host cannot be determined at this stage of my observations. Cultural methods are at present being applied and it is hoped that at a future date more light would be thrown on facts concerning the

multinucleate forms. However, as it differs from *D. mesnili* in many respects, I have named it as *Dobellina rayi* n. sp., after Dr. H. N. Ray, Protozoologist, at the Imperial Veterinary Research Institute, Muktesar-Kumaun (U. P.).

ACKNOWLEDGMENT

I am deeply indebted to my Professor, Dr. K. N. Bahl, D. Sc. (Punj)., D. Phil. D. Sc. (Oxon)., F. R. A. S. B., F. N. I., for his kind guidance and encouragement.

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EXPLANATION OF TEXT-FIGURES

Figs. 1—5.—Uninucleate trophozoites of *Dobellina rayi* n. sp.; figs. 2 and 5 show the attachment of bacteria and extraneous matter to the body of the amoeba. ×1765.

Figs. 6, 7, 8.—Specimens of *D. rayi* in which vacuolization of the cytoplasm has set in. ×2033.

Fig. 9.—An individual in which the karyosome has broken up prior to the nuclear division. ×2033.

Figs. 10, 11.—Multinucleate trophozoites. ×3000 *Ca*.

Figs. 12. 13,—Pre-cystic stages of *D. rayi*. ×1833.

Figs. 14, 15, 16, 17.—Bi—, quadri—, hexa—, and octo-nucleate cysts of *D. rayi* respectively. ×1866.

Fig. 18.—A supernucleate cyst of *D. rayi* containing 16 nuclei. ×1866.

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Articles should be as *brief* as possible. The viewpoint should be comprehensive in giving the relation of the paper to previous publications of the author or of others and in exhibiting, when practicable, the significance of the work for other branches of science. Elaborate technical details of the work and long tables of data should be avoided, but authors should be precise in making clear the new results and should give some record of the methods and data upon which they are based.

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THE NATIONAL ACADEMY OF SCIENCES INDIA

BUSINESS MATTERS

1941

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ANNUAL MEETING

The Eleventh Annual Meeting of the National Academy of Sciences, India, was held in the Senate Hall of the Agra University, Agra, at 2-30 p.m. on Friday the 13th February, 1942. Dr. Panna Lall, D.Litt., C.I.E., I.C.S., Adviser to His Excellency the Governor of the United Provinces presided. Dr. Shri Ranjan, M.Sc. (Cantab.), D.Sc. (State-France), one of the General Secretaries, read the messages of good wishes from Universities. Lt.-Col. J. C. Chatterji, M.A., Vice-Chancellor, Agra University, Chairman, Reception Committee, read his Welcome Address.

Dr. Panna Lall delivered his Address which was followed by the Presidential Address of Dr. D. R. Bhattacharya, D.Sc., Ph.D., F.Z.S., F.N.I., the President of the Academy.

Dr. Shri Ranjan read the Secretaries' Report and Education Minister's Gold Medal was presented.

Lt.-Col. J. C. Chatterji proposed a vote of thanks to Dr. Panna Lall which was followed by a vote of thanks to the Agra University proposed by Dr. Shri Ranjan.

SECRETARIES' REPORT

PRESENTED AT THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES, INDIA, ON FRIDAY, FEBRUARY 13, 1942

BY PROFESSOR SHRI RANJAN, M.Sc. (CANTAB.), D.Sc. (STATE-FRANCE), F.A.Sc., F.N.A.Sc.

We have the honour to submit the following report on the working of the Academy during the period beginning from the 1st January, 1941, and ending with the 31st December, 1941.

Annual Report.

The Tenth Ordinary Annual Meeting of the Academy was held on Saturday, the 22nd February, 1941, at 11 A.M. in the Old Viceregal Lodge, Delhi. The Hon'ble Sir Maurice Gwyer, K.C.B., K.C.S.I., D.C.L., Chief Justice of India, and Vice-Chancellor of the Delhi University, presided over the function. Dr. Shri Ranjan, one of the General Secretaries of the Academy, presented the annual report.

Lala Shanker Lall, Senior Vice-Chairman of the Delhi Municipality and Chairman of the Reception Committee of the Academy, read his Welcome Address. The late Sir Shah Muhammad Sulaiman, Kt., M A., LL.D., D.Sc., F.N.I., F.N.A Sc., Judge of the Federal Court of India, and President of the Academy, delivered his address. The Hon'ble Sir Maurice Gwyer, K.C.B., K.C.S.I., D.C.L. then made a speech, and gave away, *in absentia*, the Education Minister's Gold Medal to Dr. N. R. Dhar, D.Sc. (Lond. and Paris), F.I.C., I.E.S., F.N.I., F.N.A.Sc., Deputy Director of Public Instruction, United Provinces, Allahabad, for his paper on "Influence of Temperature and Light intensity on Photosynthesis and Respiration and Explanation of 'Solarisation' and 'Compensation' point".

Fellows and Members.

The Academy has now on its rolls 135 members who hail from every part of the country; of these 100 are elected Fellows and 2 Honorary Fellows.

Publication.

We are glad to be able to record that the Academy has made steady progress both as regards the quality and the quantity of its publications in spite of about a 100 per cent increase in the cost of publications brought about by the World War. Our Proceedings are on the exchange list of more than 170 Indian and Foreign scientific journals but during the last twelve months, due to War and censor, we have been able to exchange only with a limited number of foreign countries. During the year under report, we published four issues

of the Proceedings containing 18 physical and 12 biological original papers, the total number of such papers communicated being 60. The majority of papers, though recommended by competent authorities, could not be published for want of funds. The articles published in the Proceedings of the Academy have been highly appreciated and profusely quoted in scientific journals all over the world and have been abstracted in all the important Science Abstracts.

Finance.

The financial position of the Academy is shown in the balance sheet appended at the end of the report. The present position is far from satisfactory, our expenses being undoubtedly on the high side, more particularly in connection with our publications. This, in view of the increased cost of publication, is a serious matter, and the Council, therefore, were obliged to make a representation for an increase in the grant-in-aid received from the Government of the United Provinces. We are sorry, the Government regretted their inability to increase the grant during the current year due to the abnormal condition brought about by the World War. We are deeply grateful to the Government of the United Provinces for the grant-in-aid which we have been receiving for the last several years. We are obliged to repeat in this connection, what the Academy has been stating in previous reports, that in the first year of its existence the Academy of Sciences, U. P., as we were formerly known, received a grant of Rs. 4,000 per annum and it was in the hope that this grant would be made a recurring one that this Academy began to function. In subsequent years, however, owing to financial stringency, the Government reduced the grant to Rs. 2,000 per annum, although the Academy has meanwhile attained the status of an all-India body. We hope that the Government will now be pleased to increase suitably the present grant and make it recurring. We are also deeply grateful to His Exalted Highness the Nizam of Hyderabad for his kind donation of Rs. 1,000 for the year 1940 and 1941. We hope that other states and Universities in the country will also help us by sanctioning grant-in-aid for the work of the Academy.

Activities.

Since our last meeting at Delhi the affairs of the Academy have progressed in a satisfactory manner, and we are lucky that notwithstanding the abnormal conditions resulting from the War in Europe and Asia and the stress of economic conditions our intellectual and cultural activities and prosperity have remained unabated during the last twelve months. But at the same time we are sorry to say that the material well-being of the Academy, with which is intimately bound up its cultural activities, has not improved. The paucity of funds has stood in the way of enlarging the activities of the Academy and taking up new programmes of scientific enquiry. For the same reason, we have not yet been able to organize a well-equipped science library nor have we been able to take in hand the building scheme, although the necessity of a building where

we can house the growing library and hold our meetings is being increasingly felt. It is unfortunate that we have received no fresh donations but we sincerely hope that conditions will improve before long and our progress will not be materially influenced by the present abnormal conditions. We would, therefore, again appeal, as on previous occasions, to all those who value the organization and progress of scientific education and research in India, for the well-being and uplift of the country, for generous financial support which alone could enable the Academy to perform all its functions efficiently.

We remember that it is science itself and not scientists, that we are trying to lift to a high pedestal. We thus claim that authority shall be exercised in the light of scientific knowledge which grows continuously and with continual effect on politics, on industry, and on thought itself. Science has become an integral part of our educational system. If we, in the continually increasing contacts of scientists with public affairs, can show that we have something of great value to contribute, and that we give it freely, placing our individual interests below those of a greater purpose; if we try to understand the motives and principles of those whom we meet who may not see our vision just as we sometimes fail to appreciate theirs, then by so doing we have the best chance of bringing about the changes that we desire. It is the personal contact of the scientists, especially with those who are charged with duties to the nation, that should be promoted. We hope that after the terrible devastations of this World War it will be the duty of scientists and scientific societies to organize in the reconstruction of the post-war social structure and so help to win the peace. That is where these associations of scientific societies with the machinery of Government may mean so much.

Remarks.

We have now great pleasure to announce that the Education Minister's Gold Medal, kindly offered this year by our learned Chairman Dr. Panna Lall, D. Litt., C.I.E., I.C.S., Adviser to His Excellency the Governor of the United Provinces, has been awarded to Dr. P. K. Sen Gupta, D.Sc., Assistant Meteorologist, Indian Meteorological Office, Alipur—Calcutta, for his group of 5 papers on the "Absorption spectra of various chemicals."

We wish to offer our grateful thanks to Sir C. V. Raman, Kt., D.Sc., F.R.S., N.L., Professor M. N. Saha, D.Sc., F.R.S., F.N.I., and Professor K. S. Krishnan, D.Sc., F.R.S., F.N.I., for acting as judges to assess the papers for the award of the Education Minister's Gold Medal.

We also wish to offer our grateful thanks to all those who have very kindly scrutinized the papers published in the proceedings of the Academy.

We are glad to record that, during the year under review, the Academy secured the active services of Mr. S. N. Bhattacharya, M.Sc., as a Special Officer. We wish to express our grateful thanks for his systematic organization of our

library and reading room, in the prompt publication of our journals and for his ungrudging help and active co-operation.

Before closing the report we desire to place on record the great loss which the Academy has suffered during the year by the untimely demise of its very active Vice-President, the Hon'ble Sir Shah Muhammad Sulaiman, Kt., M.A., LL.D., D.Sc., F.N.I., F.N.A.Sc. Not only was he a towering personality amongst the scientists of the World but he was more important to us for his most valuable contributions.

FINANCIAL STATEMENT OF RECEIPTS AND EXPENDITURE FROM 1ST APRIL, 1940, TO 31ST MARCH, 1941.

RECEIPTS	Rs.	a.	p.	EXPENDITURE	Rs.	a	p.
Opening Balance on the 1st April, 1940, with the Imperial Bank..	1,165	2	3	Establishment ...	1,529	13	6
U. P. Government Grant for 1940-41	2,000	0	0	Contingency (including postage stamps, printing, stationery and allowances, etc.)	369	2	6
Allahabad Municipal Grant for 1940-41	237	8	0	Expenses of Annual Meeting (1940) held on February, 1941 ...	175	5	0
Subscription from Members ...	1,665	0	0	Auditor's Fee, (for 1938-39 and 1939-40)	95	0	0
Subscription for Life Membership	100	0	0	Printing of Proceedings of the Academy Rs. 1,686-13-0			
Sale-proceeds of Proceedings of the Academy ...	22	6	0	Purchased papers for Proceedings ... Rs. 357-0-0	2,043	13	0
Donation for Building Fund ...	100	0	0				
Miscellaneous receipts ...	110	1	9	Furniture. (Hanger & Ladder) ...	76	0	0
Bank Commission on foreign cheques	3	3	0	Bank charges on outside cheques.	11	6	0
				Available Cash Balance on 31st March, 1941, with the Imperial Bank of India, Allahabad ...	1,102	13	0
Total Rs. ...	5,403	5	0	Total Rs. ...	5,403	5	0

Account compiled by :—

P. C. MUKERJI.

SALIGRAM BHARGAVA, M.Sc.
Hony. Treasurer.

We have audited the accounts of the National Academy of Sciences, India, for the year ending 31st March, 1941, and hereby certify the accounts to be correct to the best of our knowledge, information and belief.

ALLAHABAD
21st August, 1941

G. P. JAISWAL & Co.,
Registered Auditors & Accountant.

WELCOME ADDRESS

LT.-COL. J. C. CHATTERJI, M.A.
CHAIRMAN OF THE RECEPTION COMMITTEE

At the Anniversary Meeting held on February 13, 1942.

DR. PANNA LALL, MR. PRESIDENT, LADIES AND GENTLEMEN,

On behalf of the Reception Committee and of the University of Agra, it is my happy privilege to offer you a very cordial welcome to the ancient and Royal city of Agra and to our University. We cannot help being keenly disappointed at the unavoidable absence of His Excellency the Governor to whom we had hoped to offer a respectful welcome here to-day. We are very grateful to you, Dr. Panna Lall, for honouring us by your presence, in spite of the manifold and exacting duties of your high office.

We extend to you a special welcome as a distinguished Doctor of the Agra University and also as one in whose sympathy and support we repose great hopes for the advancement and progress of this University.

My work as a touring Government Official combined with my other duties has levied such a heavy tax on my time during the last few months, that it has been physically impossible for me to devote the necessary time to the preparation of a welcome address befitting a gathering of such eminent and learned men of Science, whom we have the honour of welcoming in our Senate House this afternoon. Consequently the few words of welcome, which I propose to say, might sound strangely simple as compared with the erudite addresses delivered by former Chairmen of your Reception Committees, but while offering my apologies to our learned and distinguished visitors, I can assure them that our appreciation of the honour they have done us and the warmth of our welcome, is not in any way measured by the brevity and homeliness of this address.

We are deeply honoured in the choice made of our city as the venue of their session by the Academy of Sciences. This University is still in its infancy. Moreover, being only an affiliating University, we lack University Laboratories and Research Departments. Our painful lack of finances prevents us from offering assistance and encouragement to the pursuit of Science and research, which should be the privilege and duty of all Universities to provide.

It is only through our affiliated colleges that we can take our share, however small it may be in the pursuit and expansion of scientific knowledge and research. It is, however, a source of some satisfaction to us that some of our colleges are making an increasing contribution in this direction. In this city, one of the leading

colleges affiliated to this University, the Agra College, has reason to be proud of the work done under the guidance of Rai Bahadur Dr. K. C. Mehta. We are happy in the knowledge that his work has received suitable public recognition, in the conferment on him of a Doctorate in Science by the University of Cambridge. At another college, the Agricultural College, Cawnpore, valuable research is carried on in the Science of Agriculture, which for a predominantly agricultural country like ours is perhaps the most profitable avenue for scientific study. More recently a Faculty of Medicine has been established in our University and a Medical College started at Agra. We trust that the college now founded will in time become a great and powerful agency for the alleviation of human suffering and the dissemination of medical knowledge, the most humane of all sciences.

But if we in this ancient city have not much that is outstanding or remarkable in the domain of modern science to show, we can present to you with great and justifiable pride the monuments and landmarks which our master builders and architects have left in heritage to all lovers of art and beauty.

In this city we have the glorious Taj Mahal, the Agra Fort with its sublime Pearl Mosque and in close vicinity to our city the stately architecture of Fatehpur Sikri. It may be that architecture, in strict nomenclature, is classified as Art and not Science, yet Science is knowledge, while art is the practical application of any science. Therefore, to the mind of a layman, there is no hard and fast dividing-line between Science and Art. Gems of perfection like the Taj Mahal and the faultless proportions of the edifices in Fatehpur Sikri could not have been brought into being, except by the greatest exponents of the art of architecture, which to many minds constitutes the most pleasing of all modern sciences.

It might be well to remember that among the first fellows and presidents of the Royal Society was Sir Christopher Wren, the famous architect and the builder of St. Paul's Cathedral. It is true that we in this city have largely to live on the glory that was Agra, yet we look forward to a time, we hope not in the distant future, when once again this ancient city will take its place among the most prominent cities of modern India. The foundation of this University of Agra is an earnest of that hope and your choice of it as a place of meeting for so learned a society is a gesture of encouragement in our endeavours for the development of our seat of learning.

Gentlemen, it would be considered presumptuous on my part to dilate on any of the problems of scientific knowledge or research, which will form the subject of your deliberations. Yet there are certain quests and problems which have exercised the minds of even the most uninstructed of laymen throughout the ages.

Unfortunately often to the most pressing of these questions, learned men and scientists have been unable to find any better solution than the proverbial reply of the Sphynx.

You meet to-day in most troublous and yet exciting times. Millions of men and women are at this time asking, whether modern science has contributed more woe than weal to the life of human kind. In the midst of total war and all its horrors, they wonder if a return to the pastoral age, when Adam delved and Eve span, when there was sufficient food and enough homespun for all alike and children were reared to become the staff and support of old age and not cannon fodder, would usher in the age of bliss, the 'Satya Yuga' that the sages and rishis of our land dreamt of, or the millennium for which humanity still hopes. For not only has the abuse of modern scientific knowledge created the most deadly horrors for the human race on land and sea, but even from the skies to which our forefathers hopefully looked up for bountiful rain for their sustenance and towards which they bowed their heads, seeing behind the blue veil the abode of the Gods, we, their successors, scan the firmament in deadly fear of the death and destruction that is poured down on us and our homes from aeroplanes and air fortresses.

The simple herbs and the health-giving waters of the springs which the ancients sought after for the relief of their ailments, may appear crude before the marvels of modern medicine and surgery Yet modern man seeks to employ the results of his researches for the discovery of poisons and the culture of germs so that he may add to the sufferings of his neighbours, already sorely harassed by the scourge from the air, from the highly scientific weapons of destruction that work havoc on land, from the submarine and the mine which imperil the waters of the sea. Assiduous and prolonged study in the science of public health and nutrition, enables nations to raise a vigorous and cultured generation of young men and women, but must parents beget, nurture and educate children only to be slaughtered at the very start of their usefulness, through deadly weapons which also are the product of modern science?

No wonder, then, if even great men lose their faith in the blessings of modern science. Writers like H. G. Wells advise the banning of aviation. Mahatma Gandhi has for years preached a return to the 'Charkha' and the land, in fact, the repudiation of the fruits of all modern science. These misgivings arise in the minds of men and women, because the results of modern science and research have been so grossly abused like most other gifts of a bountiful Creator by generations of men who claim to be the noblest of His creation. We laymen still cling to our faith, we desire to see modern science and research expand and encircle the uttermost parts of our world, for the greater good and comfort of our race; but now we look to you scientists that while you add to the wealth of science, you should also find some way, some means, whereby the knowledget hat is the outcome and fruit of ages of your labour and centuries of seeking, may be saved from the misuse such as is so terrifyingly demonstrated in the present war.

Modern science is in its initial stages in our country. All enlightened nations have some special contribution to make to the civilisation of each age. We hope that the growing number of scientists in this country would make it their mission to offer some contribution towards the prevention of the abuse of scientific knowledge. Knowledge and art in old India created things of joy, such as we see in this old city of Agra, systems of medicine which have not yet out-worn their efficacy. Their researches and seekings after the sublime gave to this world codes of religion and systems of philosophy which still hold the allegiance and admiration of mankind. Gentlemen, may I with deep respect submit for your consideration that you, the modern scientists of our land, should ponder over this vast problem and help in some measure to restore the faith of this generation in the beneficence and benison of the sciences.

But even to-day I will not close on a note of pessimism such as the tempo of the present times must inevitably impress on the most optimistic. I still believe that the years we are passing through are as the deepest darkness that immediately precedes the dawn. I look for a speedy change in this sorry order yielding place to a better and happier scheme of things, and in the words of Tennyson I would urge you to :—

Let knowledge grow from more to more
But more of reverence in us dwell;
That mind and soul, according well,
May make one music as before.

For yet we trust that somehow good
Will be the final goal of all,
To pangs of nature, sins of will,
Defects of doubt, and taints of blood;

I can but trust that good shall fall
At last—far off—at last, to all,
And every winter change to spring.

PRESIDENTIAL ADDRESS

PROFESSOR D. R. BHATTACHARYA, PH.D., D.SC., F.Z.S., F.N.I., F.A.SC., F.N.A.SC.

As a successor to the late Sir Shah Mohammad Sulaiman, I feel greatly honoured at being given the opportunity of delivering an address to this august body. The presidential addresses delivered during the last 25 years at the various scientific gatherings hardly leave any room for taking up a new theme of a popular nature. I have, therefore, decided to give here a review of some aspects of Cytology, in the investigation of which I and my pupils are at present engaged.

The Vacuome Theory

The science of Cytology deals with the study of cells. The cell has generally been defined as "a unit of living matter." Whether life arrived here from another planet or originated from some protoplasmic material remains still unknown. What is certain is that life began in a very simple form. The simplest animal consists of living material or protoplasm, in a cellular form. All living cells have the remarkable power of converting non-living matter into living protoplasm. Cells can be isolated from the rest of the body and kept alive. The total number of cells in the human body is said to be about a thousand English billions. Every living cell is a "potential individual" containing in its own body all that is necessary for life. Life, as a matter of fact, arises from pre-existing life.

Knowledge is already so diversified that we have to partition up the task amongst a panel of specialists. But the problems interlock and shift from one field to another. Modern Cytology has developed far enough for the attack of fundamental problems and is now the starting point of great progress in physiology and pathology. It has solved at last the riddle of the fertilization of the egg and the beginnings of individual life. Every field of biological research has been illuminated by our present knowledge of the cell. As Cowdry says, "The ultimate aim of Cytology is the discovery of principles which cause a cell to be simultaneously an individual and one of the building stones of the organism."

If we start our study with a simple cell, *e.g.*, an animal egg, we find that it contains, apart from the nucleus, certain formed bodies called Golgi bodies and mitochondria. Yolk bodies and fat and some other cell-components may also be found. To the latter category, probably, belong the vacuoles. This cell component has been the subject of great controversy during the last 15 years, and will thus be discussed here in detail.

Few problems of modern Cytology have aroused greater interest than the homology of the so-called "Vacuome" with the Golgi apparatus, first emphasised for the animal cells by Guillermond, and Parat and Painlevé (1924). Earlier, the well-known plant spaces colourable with vital dyes had been described in a series of papers by P. A. Dangeard (1916—'20), and P. Dangeard (1920—'24). Guillermond in an extensive series of studies, which have continued down to the present day, carried on the vital staining of these spaces with neutral red and came to the conclusion that the vegetable cells contain two independent morphological entities—the vacuome and the chondriome. The Golgi network of the animal cells, according to this author, has its equivalent in the reticular vacuolar system of vegetable cells.

Parat and Painlevé elaborated this conception in the animal cells Investigating the salivary glands of Chironomous larva by means of neutral red staining, Parat and Painlevé found that the dye was first "fixed" by numerous small vacuoles. At the moment of the discharge of the secretory granules, the latter somehow fluidify inside the vacuoles that contain them and coalesce together to form "un magnifique appareil reticulaire." The secretory material is discharged in the intercellular canaliculi and the apparatus gradually disappears. Parat and Painlevé think that this temporary structure formed by the confluence of neutral red vacuoles and the fluidified secretory granules represents the Golgi apparatus. The discrete vacuoles, seen with and without the application of the vital dye, on being treated according to the technique of Da Fano or with osmic acid, present the appearance of irregular vesicles or thick-set 'batonnets.' The two aspects of the Golgi bodies, the discrete dictyosomes of Perroncito and the well-known Golgi network thus find their parallel in the isolated and coalesced vacuoles of Parat. The network may not necessarily be always present as a normal structure in the cell. According to Parat, the classical Golgi apparatus is an artefact created by the action of fixing reagents. Parat and his collaborators investigated numerous somatic and germinal tissues of animals and brought forward proofs in support of their original contention. In 1925, Parat and Bergeot reported that the classical Golgi apparatus is not composed of a lipoid substance, as has been generally assumed by the English and American cytologists. This conclusion was reached from the results obtained by the application of the technique of Dietrich.

Parat, however, was not slow to recognise the fact that Golgi apparatus had been described by other competent cytologists in the shape of chromophil rods in the male germ cells of several animals, which could not be explained away by his Vacuome hypothesis. These structures are quite easily observed intra-vitam, and without the application of any dye at all. Parat (1927) contends that Gatenby's conception of the Golgi apparatus is based entirely on his researches conducted on the male germ cells, which do possess a so-called Golgi apparatus. Parat accepts its lipoproteid nature and admits that it is strongly resistant to the action of physical agents

like variations of osmotic pressure, micro-dissection, etc. He does not consider these dictyosomes of sperm cells as homologous to the classical Golgi apparatus. According to him, they are simply modified mitochondria which he calls "lepichondriosomes" or simply "lepidosomes." In the animal cells, according to Parat, there exists at the "pole mondial" a zone essentially characterised by the presence of the vacuome, a great quantity of diffuse lipoids in contact with the vacuoles and the chondriome. This area Parat calls, "zone de Golgi." The chondriome of this zone shows a particular feature ; it is the "Nebenkern" of the pulmonates, the pseudo-chondriosomes or central capsules of Heidenhein, and the filaments of Platner. Benda, Popoff, Fauré-Fremiet and Karpova have suggested that these structures are of mitochondrial origin. In addition to these elements which, according to Parat, have been wrongly called dictyosomes, there occur in the "zone de Golgi", the "vacuolaire" elements which are the real dictyosomes. In subsequent papers, Parat and his collaborators have further developed this conception of 'chondriome actif' and 'la zone de Golgi'. Parat's theories have received a general measure of support from the majority of French cytologists, but outside France they have generally met with adverse criticism. It is quite unnecessary to take into account the works of the pupils of Parat, *e g.*, Hibbard, Volkonsky, Dornesco, Jacquiert, Gambier, Bergeot, etc., as the general conclusions embodied in these works nearly always uphold Parat's hypotheses. Parat, moreover, has been strongly supported in his attitude towards the classical Golgi material by Hosselet (1931-32), who finds that in the ovarian elements of certain Dipterous insects typical reticulate structures simulating closely the classical Golgi bodies can be brought to view by using specific mitochondrial methods like Zenker-Helly. Whereas Parat is prepared to concede that the dictyosomes of Perroncito, Gatenby and Bowen, etc. are lepidosomes or modified mitochondria (Guillermond's chondriome actif), Hosselet summarily rejects the conception of different kinds of mitochondria. It may be noted here, that of the numerous other workers who have investigated the oogenesis of insects, *e.g.*, Govaerts, Nusbaum, Gatenby, Payne, Nath and the present author and his pupils, hardly anyone gives such figures of mitochondria as Hosselet does. There must be some error in Hosselet's work. His conclusions about the nuclear origin of mitochondria are similarly open to serious objections.

Covell and Scott's studies (1928) have also furnished a certain measure of support to Parat's vacuome theory. Covell and Scott studied the cells of the ventral horn and the spinal ganglia of the mouse. They observed the impregnation of the neutral red bodies with the osmic acid directly under the microscope and reported a curious alignment of the neutral red elements, although as Beams (1931) correctly points out, they were probably never able to see the formation of a net-work after they had been fixed. Nevertheless, Covell and Scott claimed that their findings offered a strong support to Parat's theory, that the Golgi apparatus does not exist as

such in the living cell. A certain number of authors who have investigated the cytoplasm of certain Protozoa from this standpoint have presented reports which may be considered to be in favour of the vacuome theory (Hall, 1930 & 1931; Chatton and Grassé, 1929; Hall and Nigrelli, 1931; Grassé, 1925; Nigrelli, 1929; Joyet-Lavergne, 1926; Cowdry and Scott, 1928; and Volkonsky, 1929). Hall (1931) thinks that in attempting to recognise the Golgi material in the Protozoa the following characteristics should serve as the main criteria; (1) consistent impregnation with osmic acid; (2) resistance to the bleaching processes after osmification; (3) consistent impregnation with silver; (4) general similarity of forms in different Protozoa; (5) occurrence of these bodies in Protozoa in general. According to Hall, it is only the vacuome that fulfil all these conditions in the Protozoa. Hence, writes Hall (1931), "it would be seen that the recognition of the vacuome as the Protozoan Golgi material is more logical than attempting to identify the stigma of Euglena, the contractile vacuole, the parabasal apparatus of certain flagellates or other specialised organelles as Golgi apparatus." Joyet-Lavergne (1926) likewise noted the close similarity between the neutral red globules and the previously demonstrated osmiophilic bodies and came to the conclusion that the types of structures revealed by these two different methods must be identical. To the objection of Beams and Goldsmith, that, "..... bodies stained by neutral-red and subsequently impregnated by osmic acid may be due to the direct chemical reaction between the osmic acid and the neutral-red, instead of the action of the osmic acid upon the preformed contents of the Vacuome," Hall replies that the subsequent impregnation of neutral-red bodies is not the only basis on which the homology is established, but the striking similarity of the neutral-red bodies with the osmiophil and argentophil elements is also a great consideration. Nevertheless, it may be emphasised that in Protozoa the recognition of bodies homologous to the "Apparato reticolare" is an exceedingly complicated affair, and the recent works of Gatenby and his pupils on the Protozoan Golgi apparatus make it clear that Hall and his co-workers were not correct in identifying the Protozoan Golgi material.

A number of tissue-culture workers also believe in the original hypothesis of Parat that the Golgi apparatus is merely the artificial coalescence of vacuoles stainable in neutral red. A typical Golgi apparatus in the tissue-culture cells has however been clearly demonstrated by several authors, *e.g.*, by Vasquez-Lopez, Richardson, Ludford, Saguchi, Gatenby, Mac Dougald, etc.

From the foregoing account it is clear that although Parat's theories have received a certain measure of support from a number of cytologists, a considerable body of evidence has been gradually accumulating which may be considered seriously detrimental to his views. Of these, the most emphatic are a number of works reporting the simultaneous existence of the Golgi bodies and the neutral-red vacuome in the same cells. The present author in collaboration with Das (1929) and with

M. D. L. Srivastava (1935) showed that neutral-red vacuome and Golgi bodies could be observed simultaneously in the young living oocytes of Columba. Similarly, Hirschler (1929) in the spermatocytes of Lepidoptera, Hirschler and Hirschlerowa (1930) in the male sexual cells of Gryllus compestris, and in certain categories of somatic cells in the larva of Phryganea grandis L (1928), Hirschler in the spermatocytes of Phalera bucephala L, and Dasychira selenitica (1928), have shown the co-existence of the Golgi apparatus and vacuome. Gatenby (1929) worked out the separate rôle of the neutral red bodies and Golgi elements in the male germ cells of Cavia, Helix and Abraxas. Similar results have also been reported by Tretjakoff, Grabowska, Rumjantzew, Monné, Voinov and Pollister.

Parat, however, as we have seen, urges that the dictyosome of the male germ cells are not "vrais dictyosomes" but "faux dictyosomes." They are simply modified mitochondria, "chondriome actif" or "lepidosomes." This, if correct, would render the simultaneous demonstration of the vacuome insignificant. But the moot point is, whether there is absolutely any justification, whatsoever, for applying a new name to the structure already known. What is the ground for considering the dictyosomes to be chondriome? Throughout the extensive series of papers written round the vacuome by Parat and his associates one fails to find a single valid reason for this assumption. Parat (1928) asserts that such bodies (dictyosomes of Perroncito, Gatenby, etc.) are very resistant and found only in germ cells. Gatenby might have retorted by saying that it is possible to show the similarly resisting bodies in somatic cells, *e.g.*, gland cells. Parat himself (1931) sketches such bodies in the "pelvienne" gland cells of Triton. The structures which Bowen, Nassonov and Ludford label as the Golgi bodies, Parat calls "chondriome actif." That is to say, Parat's second hypothesis does not deny the existence in the living cells of the osmiophil elements which a great number of cytologists have been describing, but simply applies a different name to them, without adducing sufficient cause for this change. Besides, the workers who have repeated Parat's investigations on the salivary gland cells of chironomous larva do not confirm Parat's results. Krjukowa (1929), Beams and Goldsmith (1931) and Gatenby (1932) make it clear that Parat and Painlevé at the time of their original publication simply missed the Golgi bodies, which are, undoubtedly, present. Krjukowa states that the impregnated net-work which Parat considers to be the Golgi apparatus is really the intracellular secretory canaliculi which may contain secretory products. Similarly, Saint Hilaire (1927) figures and describes intracellular canaliculi which become filled with secretory material stained with neutral red, and give rise to a massive net-work. Such intracellular canaliculi are also shown by Beams and King (1932) in the salivary gland cells of grasshoppers and have obviously nothing to do with the typical Golgi bodies, which are discrete platelets and are figured and described as separate entities existing side by side with intracellular canaliculi. In justice to Parat it may

be mentioned that he was not unaware of the existence of such intracellular canaliculi as Beams and King seem to think. He clearly mentions them in his work (1928). Nevertheless, a comparison of Parat's figures and those of Saint Hilaire (1927), Beams and King (1932), and Gatenby (1932) makes it obvious that Parat and Painlevé (1928) blundered in homologizing the massive net-work formed by the secretory canaliculi with the Golgi elements, which remain discrete throughout and do not form such a net-work. Gatenby (1932) showed that the neutral red exerts an injurious effect on the architecture of the cells and creates cavernous spaces which get filled with neutral red and appear as vacuome. These, according to this author, are artefacts, pure and simple, and have nothing in common with the Golgi elements which exist simultaneously with and independently of the artificial neutral-red bodies. This would go to show that neutral red can artificially create bodies which were not pre-existent in the living cells.

It has been held by certain cytologists that whereas acidic dyes give rise to neoformation in the cell, the basic dyes like neutral red stain only the preformed elements. That this is not so, has been amply demonstrated by the work of Chlopin who has carried out an extensive series of investigations on the effect of vital dyes on a wide range of somatic cells. Chlopin finds that in addition to staining preformed granules, neutral red induces secondarily formed bodies which contain a peculiar substance stainable with basic dyes, which he calls "Krinom." Besides, the preformed granules which stain with neutral red are often the secretory products of the cell and cannot obviously be considered homologous to the "vacuome." This implies that neutral red is not specific in its action and can stain various types of cellular elements. The prozymogen granules of the pancreatic cells of salamander, according to Gatenby (1931), likewise stain with neutral red. The volutin granules of certain Protozoa (Patten and Beams, 1936) also stain with neutral red. Ludford (1930) found that on injecting neutral red into living mice dye droplets appear in the acinar cells of the pancreas. This segregation of the dye droplets results from the vital activity of the cell and is not due to a passive staining of the preformed droplets. Ludford was able to fix and preserve the neutral-red bodies in permanent mounts, following certain techniques, and could show the simultaneous existence of a typical Golgi net-work somewhat altered and broken on account of the injurious action of the neutral red and the "vacuome." Similarly, Avel (1925) pointed out in the very beginning that neutral red is not specific for vacuoles and that the presence of permanent vacuolar system in all animal cells is unproved.

In the face of such evidences, which deny the specific action of the neutral red, Parat's vacuome theory cannot be considered as established. A permanent vacuolar system stainable with neutral red may exist in the plant cells, but that in itself is no justification for considering that a similar system must exist in the animal cells as well.

The Ultra-Centrifuge

A very important part in settling the controversies regarding the morphology and functional significance of the Golgi apparatus has been played by the ultra-centrifuge. Before its invention by J. W. Beams (1930) of America, electrically driven centrifuges were in use, and the investigators of oogenesis often employed this machine in order to stratify the cytoplasmic components in discrete layers. This facilitated a close examination of the inclusions. As early as 1910, Conklin noted the effects of centrifuging the eggs of certain molluscs. He pointed out that on centrifuging the eggs at a speed producing a pressure of about 600 times that of the gravity, three distinct strata were formed. The upper one was greyish and consisted of a light substance, the middle one was clear, and the lower layer contained a heavy substance and was yellow. Gatenby (1918) also discovered three distinct layers in the centrifuged eggs of Limnœa stagnalis. The upper layer consisted of yolk discs, the middle layer of clear cytoplasm and the lower layer of Golgi bodies and mitochondria. These three layers obviously correspond to the three layers of Conklin, *i.e.*, the "grey substance," the "clear substance" and the "yellow substance." Only Gatenby was able to pronounce on the nature of the substances composing the three layers. Brambell (1924) studied the effects of centrifuge on the oocytes of Helix aspersa and Patella vulgata, in order to determine particularly the nature and origin of yolk. In the mature oocytes of Helix so treated three distinct layers, "clear-cut and sharp," were observed, and they showed "little tendency to merge into each other." The upper layer consists of Golgi yolk which are obviously fatty in nature, the middle layer of Golgi rods, which, however, are not confined to this zone alone, but are scattered all over the ooplasm, and the lower layer consists entirely of mitochondria. The upper layer does not form more than 10 per cent of the whole egg. The nucleus occurs in the middle zone. The same three layers are found also in the mature centrifuged eggs of Patella, with the difference that here the upper zone consisting of Golgi yolk bodies is made up of about 75 per cent of the entire egg and contains the nucleus. The middle clear zone and the lower layer consisting of mitochondria are much smaller and the Golgi elements, as in Helix, are distributed all over the cytoplasm. Vishwa Nath has studied the oogenesis of a large number of animals and in almost all cases he has centrifuged the oocytes investigated. In Lithobius forficatus he observed three layers in centrifuged eggs. The upper layer consisted of fatty yolk bodies. The middle zone, which also contained, towards its upper end, the nucleus, was filled with the Golgi elements and mitochondria. The lower contained "true vitelline yolk granules." The same three layers are also found in the oocyte of scorpions. The upper layer consists of Golgi yolk bodies, and the lower layer of proteid yolk. The middle zone contains the mitochondria and the Golgi elements and also shows the nucleus. Centrifuge

experiments on the oocytes of the spider Crossopriza lyoni (Blackwall, 1928) gave results which are identical with those obtained in the case of Lithobius and scorpions, Euscorpius napoli. In Luciola (1929), again, the same three layers are encountered, with this exception that a few osmicated "Golgi vacuoles" are found also in the lower zone which is chiefly occupied by the albuminous yolk, which Nath thinks " is due to mechanical causes inasmuch as they are caught between the big yolk-discs." Similar results are also obtained from the centrifuging of the oocytes of the mosquito, Culex (1929). Such a stratification of the cytoplasmic components has also been obtained in the oocytes of various animals by the present writer and his pupils in the Allahabad University Laboratory. In the butterfly Appias narendra the present author and Shyam Mohan Srivastava (1935) found the upper zone occupied by the fatty yolk bodies and the Golgi bodies, then came the albuminous yolk and last of all the mitochondria. It will be observed that nearly all the cytoplasmic constituents of the eggs were thus aggregated in separate zones, with very slight intermingling and whereas the fat bodies occupied the centripetal pole being the lightest, the mitochondria occupied the lowest—the centrifugal pole, being the heaviest. Jägersten (1935) describes the inclusions in a centrifuged egg of Rana temporaria which unfortunately had not yet formed proteid yolk. The uppermost layer contained fat bodies which had been dissolved out. The distorted nucleus is shown occupying nearly the entire stretch of the cytoplasm, containing the nucleoli towards its centrifugal pole. Immediately beneath the fatty vacuoles are found two masses of lamellae. The middle zone which consists, for the most part, of clear cytoplasm contains a few scaly Golgi elements in the upper portion. About the middle of the oocyte is a well-marked "Cytonephelium." After the clear zone there occur three more layers—those of argentophil "mikrosomes," mitochondrial filaments and, last of all, argentophil granules and vacuoles. It may be mentioned that of all the investigators of oogeneses Jägersten seems to be the only one who has been able to identify a definite cytoplasmic structure observed in the fixed cells which can be considered homologous to Parat's neutral-red vacuole. And these bodies get arranged in a single layer at the centrifugal pole on being subjected to the centrifugal force. But this result has yet to be confirmed.

It would be obvious from a perusal of the literature that the workers who used centrifuge in the study of the oogenesis often found that fat bodies are stratified at the centripetal and the mitochondria or albuminous yolk at the centrifugal pole. But it is apparent that the inclusions are separated only partially, and in view of the fact that the ordinary electrically driven centrifuge generally takes more than an hour to stratify the components, it has not proved of any particular value in settling the vacuome controversy, as it could not be easily combined with the intravitam studies.

The air-driven ultra-centrifuge, on the other hand, has been greatly useful in this direction. Beams and King (1934) ultra-centrifuged the uterine cells of guinea-pig before fixing them for the study of the Golgi elements. They found that the Golgi elements under the centrifugal force are driven from one pole to the other by a streaming movement. On this ground, Beams argued, and with considerable justification too, that the Golgi bodies were of semi-solid nature and could not possibly be of a vacuolar type. Since then many papers have appeared on the subject. One of the earliest was Miss Norminton's (1937), who worked out the oogenesis of Lumbricus by means of the ultra-centrifuge and settled the controversy between Harvey (1925), Gatenby and Nath (1926), and Nath (1930). She found that the cytoplasmic components are broadly stratified in three zones. At the centripetal pole of the cell are fat bodies, a number of small spherules, which had been mistaken by Nath (1930) for the Golgi bodies. Below this lies the nucleus. The Golgi elements, discrete dictyosomal bodies, also lie in this zone, below and besides the nucleus. Immediately beneath, there is a belt of mitochondrial granules. The centrifugal pole of the egg is occupied by a fluid substance of heavy specific gravity. The neutral red bodies occur in the zone occupied by the Golgi elements. Norminton, however, thinks that the neutral-red bodies are artefacts, since these are found scattered throughout the cell, when it is ultra-centrifuged and then stained with the neutral red. Beams, King and Risley studied the effects of the ultra-centrifuge on the eggs of Rana aurora and noted three layers:— 1. yellow or white fatty layer occupying the centripetal pole, 2. a clear zone almost entirely devoid of the inclusions, and 3. a layer of proteid yolk occupying the centrifugal pole of the oocyte. Singh (1938) in the course of his study on the oogenesis of Vulture, ultra-centrifuged the oocytes and recorded four layers of the formed inclusions. Occupying about half the oocyte at the centripetal pole, lie sudanophil fat spherules and cholesterol. Next occurs a layer of Golgi elements forming a "regular band." The nucleus is generally in this zone, sometimes just below it. The third layer in order is formed of yolk which are produced by the mitochondria. The last layer, occupying a centrifugal pole of the cell, consists of mitochondria which are, thus, found to be the heaviest cyto-component in the oocytes. Singh also notes that on staining the ultra-centrifuged eggs with neutral red, the vacuome are found scattered throughout the cell. He, therefore, concludes that neutral red vacuoles are artefacts, a conclusion also arrived at by Norminton (1937) for the same reasons.

Beams and King in a recent paper on "the Cytoplasmic components and inclusions of the developing guinea-pig egg" describe the effects of ultra-centrifuge. As usual, they found the mitochondria heavier than the cytoplasm, which, in consequence, were driven to the centrifugal pole of the cytoplasm. The yolk nucleus in the young one is usually near the middle of the cell. In some cases, however, the

yolk nucleus may be displaced among the mitochondria at the centrifugal pole of the cell. The fat bodies, which darken in osmic acid, are always aggregated at the centripetal pole. Yolk granules are found collected centripetally to the mitochondria in "the centrifugal pole of the egg." Another recent paper on the subject is that of Singh and Boyle (1938) who used the eggs of the stickleback as the material. On ultra-centrifuging five distinct layers were established. At the centripetal pole was the usual accumulation of the fat bodies. Next came a layer of clear cytoplasm followed immediately by a belt of Golgi bodies. Beneath the Golgi elements is a wide zone consisting of proteid yolk bodies, derived according to the authors, from nucleolar extrusions. The centrifugal pole is occupied by mitochondria, nucleoli and nucleolar substance.

It may be mentioned that for the purpose of the stratification of the formed cytoplasmic bodies, it is necessary to ultra-centrifuge the material for a comparatively brief duration. For example, Singh (1938) worked the ultra-centrifuge only for 15-20 minutes, Beams and King (1938) for 30 minutes, Singh and Doyle (1940) for 10 minutes, Daniels (for Gregarines of Tenebrio) only for 3 or 4 minutes.

The results obtained in the aforementioned studies may be summarised to show that on being ultra-centrifuged the Golgi elements and mitochondria occupy two absolutely different zones. If the Golgi elements were simple modified mitochondria, as Parat's Lepidosome theory would have us accept they would probably not be separated so widely. Again, whenever ultra-centrifuged eggs have been stained in neutral red the vacuolar bodies have appeared irregularly scattered, whereas if they are really pre-existing structures they should be displaced and stratified just in the same way as the other inclusions are, *e. g.*, Norminton (1937), Singh (1938), Singh and Boyle (1940).

Daniels (1938) adopted the same means in order to study the inclusions of the Gregarines of Tenebrio. Some of the Gregarines were stained in neutral-red after centrifuging. All the usual inclusions were definitely stratified, but red globules appeared all over the cytoplasm, showing no relationship to the other inclusions. This indicates that the neutral-red bodies first arose after centrifuging under the action of neutral red, and were not pre-existent. Singh (1938) in his studies on the cytology of Amoeba proteus comes to entirely different conclusions. He found the air-driven ultra-centrifuge too powerful for Amoeba proteus and had to take recourse to electrical centrifuge. Some Amoebae were centrifuged after staining with neutral-red and it was observed that neutral-red globules were stratified in the middle of the cell. The most striking fact, however, is that the neutral-red globules were also banded in the same way if the Amoebae were first ultra-centrifuged and then stained with neutral red. This indicates that the neutral-red globules described in Amoeba by Singh are pre-existing structures and not bodies formed under the influence of the dye itself. These very

neutral-red globules were, however, also described by Patten and Beams (1936) who studied the effect of ultra-centrifuge on some free-living flagellates. They found that these are volutin granules as had been shown earlier by Baker (1933) in Euglena gracilis. Another striking fact is that Singh does not consider any structure in Amoeba corresponding to the Golgi apparatus of the metazoan cells, although Brown (1930) and Mast and Doyle (1933) show that Amoeba does possess structures homologous to the Golgi elements. In the ultra-centrifuged cells according to Brown (1930) the fat bodies occupy the centripetal pole and immediately beneath them occur granules which may be considered rudimentary Golgi bodies.

Similarly, Sigot (1931) was able to identify 'l' appareil' in Euglena (1931) and mentioned that he tried in vain to stain this structure with neutral red and Janus green B. Gatenby and Singh in their studies on Euglena agree with Sigot that what they call the Golgi apparatus in this Protozoan 'does not stain in neutral red' and further state that there is no reason for supposing that the neutral staining volutin granules have any connexion or homology with the metazoan Golgi apparatus. Thus it would be seen that the vacuome and lepidosome theories of Parat do not find any support from works done by means of the ultra-centrifuge. The neutral-red bodies are generally not stratified, and where they are stratified as in certain Protozoa (Patten and Beams, 1936 and Singh, 1938) they are shown to correspond to volutin granules which are not homologous to the Golgi apparatus of the metazoan cells. The large number of papers published from the Zoological Laboratories of the Allahabad University agree in the main with the results arrived at by Beams and by Gatenby and his pupils. The ultra-centrifuge has solved the problem of identification of cell components, but it must be confessed that we are far yet from understanding the true nature of vacuome and neutral-red granules and their origin. The credit must go to Parat, however, for focussing our attention on this problem.

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ADDRESS OF THE CHAIRMAN

ADDRESS BY DR. PANNA LALL, M.A., B.Sc., LL.B., D.LITT., C.I.E., I.C.S., ADVISER TO HIS EXCELLENCY THE GOVERNOR, UNITED PROVINCES, AT THE ELEVENTH ANNUAL SESSION OF THE NATIONAL ACADEMY OF SCIENCES, INDIA, HELD AT AGRA ON FEBRUARY 13, 1942.

MR. PRESIDENT AND MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES:

His Excellency the Governor of these provinces has entrusted me with a message, which I should first deliver to you.

His Excellency's Message—

> "Two years ago I had the honour to attend the annual meeting of the National Academy of Sciences and I sincerely regret that it has not been possible for me to attend the meeting at Agra this year. Two years ago I spoke of the mad policy of one nation, or perhaps more accurately, of one man which, apart from its more direct results, has had the indirect result of handicapping throughout the world scientific investigation, and which has turned the ingenuity of man to inventing means of destroying life rather than of preserving and improving it. Since then the conflict has spread throughout the world, but a time will come again when swords can again be beaten into ploughshares and spears into pruning hooks and it is well that we should maintain the continuity of scientific thought designed for other purposes than human destruction. The National Academy of Sciences is designed to secure that continuity and I wish its meeting this year every success. I am glad to say that the Provincial Government has found itself able to give a recurring grant this year to the Academy in place of the non-recurring grants given in previous years and I know that this contribution to your resources will be well repaid."

I thank you for the honour you have conferred upon me by inviting me to inaugurate this session. The importance and weight which attaches to this Academy is evident from the list of distinguished scientists who are its members and from the galaxy of eminent men which I see resplendent here today. It is a pleasant coincidence that you are meeting today in this city of Agra, where I spent many happy years of my academic life.

It would indeed be presumption for one, with my slender equipment, to speak in such an assemblage either on the value of the work which you have done or to say to you what you should do; or again to attempt to dogmatize on the charge which is sometimes levelled against Science that it is responsible for the misery and injury which has been inflicted by the warring nations and that therefore its mischievous activities should be curbed, if it should not be altogether anaesthetized and laid at rest for a time, like a lunatic in a padded cell. But I cannot refrain

from taking advantage of this opportunity to make a few observations. My two immediate predecessors, in the role which I fill today, referred (with the humility of the real savant) to the exclusively classical education which they had received. Unlike them I have had the unusual good fortune of receiving a classical as well as scientific education. And though that justifiably labels me as jack of both, yet it gives me an advantage also. For without being open to the charge of partiality to science, I can appreciate, and offer my tribute of admiration to, the valuable work which has been done by your members in expanding the horizons of knowledge; dealing on the one hand with the immensities of the suns and the stars, and on the other with the unimaginable minuteness of nuclei and electrons. But I would not be so foolish as to go into any further details.

Science and the Horrors of War—

The statement that Science is to be held responsible for the suffering and misery which has been and is being inflicted this minute on our fellow-men—but from which Providence has so far saved us—is one which I never thought would need a solemn and serious refutation, until latterly when I heard that view expressed by responsible speakers, whom I hold in great regard and esteem. I cannot brush this aside as cheap or prejudiced criticism. I would, therefore, take this opportunity with your permission, to submit a few considerations to the contrary, although they must needs appear to you obvious and even elementary. While not yielding to any in my love for classics and the fine arts, I am utterly unable to join hands with those who would condemn science as the source of our misfortunes and would crush its activities. This unjust attitude has recently provoked a scientist to make a spirited retort. He asks that the Government of the world should be handed over to scientists who might achieve greater success than the politicians in stopping this awful succession of wars. Without subscribing to that extreme demand, I would say, with the full knowledge of the horrors of the past two and a half years, that we still want science and more science—pure science; applied science; technical science.

The fact that the knowledge acquired by science has been put by some to unworthy uses and has resulted in human suffering may denote a failure of religion or philosophy; but is surely not sufficient to prove the iniquity of scientific pursuit. It should rather furnish a reason for educating those unworthy persons in the proper ideals of human conduct—in other words—Moral Science, and I would say that the noble appeal addressed by the learned Vice-Chancellor today to scientists to prevent the misuse of science should, I venture to submit, be more appropriately addressed to those who wield political power. Human passions were not less brutal before the advent of electricity and radio-activity. Humanity exhausted all its resources in devising the lingering tortures of the poisoned arrow and daggers

which opened inside the body with expanding jagged edges. And right back in the dawn of our race, how could our first ancestors have succeeded in establishing their supremacy over the four-tusked elephant or the sabre-toothed tiger without the use of weapons fashioned after the scientific knowledge then available? Would you condemn the discoverer of iron or copper for the use of the battle axe; or blame the stone club which the early male employed with such success to strengthen his matrimonial suit? But for these early and patient researches in the properties of stone, iron and copper, there would have been little of our boasted civilization.

Again, quite apart from the visible and tangible enemies with which our forbears had to contend, science has given us information about a host of others, too minute to be seen or felt, which nevertheless are deadly. The typhoid or the cholera germ is no less deadly than the karait or the boa constrictor. It is science alone which can discover for us, first the existence of these hidden enemies and next the way of checkmating them. We must have, can have, nothing but praise and encouragement for scientific research. The tragedy rather is that knowledge is co-existent with power, and Providence has given us free will to employ that power as we list. That power or energy—*Shakti*—has a dual aspect, one gentle and the other fierce—the *Gauri* and the *Kali*—and Man, the supreme purpose of evolution, has yet to learn how to understand and propitiate both.

In our ancient books there is a story of a research student who was eager to acquire mastery over the forces of nature. He obtained the power to burn up anything which he touched. And immediately he tried to employ that knowledge on the very person to whom he owed it. But Providence could not tolerate such wickedness, and in the end all that he succeeded in achieving was to burn himself to ashes with his own power. May be that that immortal story is being enacted once again before our eyes.

Science and War Effort—

Our immediate concern is with the actual circumstances surrounding us. The War is there as wars have always been. Like a vast devastating prairie fire, it is continuing its relentless march and ours is the only great country that has so far escaped; but its horrible hungry tongues are even now licking our borders. Is this, I ask, the time to put science away in cold storage, or is it the time when the clear duty of all scientists is to make the fullest use of their intellect and resources, and together to devise the most effective means of counteracting the menace that stares us in the face.

Gentlemen, bear with me when I pause and consider how helpless we should be without science. It is only with the help of science that the ships of the navy are still sailing on the high seas, bringing us food, medicines, and machinery. Our

valiant soldiers, whether in the Mid-East or the Far East, must maintain touch with us by ether, air, or sea. You will recall how the advent of the magnetic mine and the accoustic mine by the enemy paralysed our shipping and our communications for a brief while till scientists—you—came to our rescue. So too against each new diabolical engine of the enemy must you discover an effective defence, and that before it becomes too late. The transport of troops; the repatriation of the wounded and the sick; the surgical treatment of the maimed and the mutilated—all these would be impossible without the aid of science. It is to the scientist that the layman appeals for advice how to defend his home and people against the explosive, the incendiary, or the anti-personnel bomb.

The long continuance of the war must inevitably cause a shortage of vital commodities. It is to you that the world will look for substitutes, alternatives, or synthetic products, for many a natural substance. It is your researches which will teach us how to employ the available resources to the greatest good of the greatest number, so that we may preserve our healths and stand up squarely to the attack. Without science, War effort will collapse like a castle of sand; and the gruesome spectre of death and devastation will stalk this our fair land. With the help of science, we may be able to survive this catacylsm and after the war may be able to piece up such bits of civilization as may still be left and start building a new world with new hopes and new aspirations. In that task of reconstruction, scientists will take a very prominent part. And while the importance of research in pure science will not diminish, these and similar practical problems of the war and of the immediate future after the war must also claim the deepest attention of yourself as of the state. It will no less be the duty of the State to collaborate with you and to provide the necessary funds for the purpose.

The Scientific Attitude—

I have so far only referred to the objective facts of science, its discoveries of matter and energy and invention of machines. Great as has been the contribution of science to the happiness and welfare of mankind by these objective items, the debt which humanity owes to science is, however, much wider. Science has given to the world a new method which has wrought a revolution in the entire realm of human thought and activity. What are the distinguishing features of this method?

The scholar who inaugurated your session last year described the merits of classical education in these eloquent words—

> "The severe mental discipline which it provided strengthened and invigorated the mind, taught us habits of accuracy and concentration, inspired us with an ardent love of truth, enabled us to grasp the general principle implicit in a series of facts or phenomena, and instructed us in the processes of reasoning and logic. Indeed it did more; for it did not neglect the emotional side of human life and it opened our eyes to the beauties of art and literature."

A truly beautiful prospect this; but may I, with all humility, claim for Science almost all this and a great deal more –

> The devalution of tradition and of authority as such; the insistence on personal observation and experiment; the search for unbiassed evidence; tireless patience never losing hope; the sorting out of data and conclusions and their orderly classification; exactness of observation leading to exactness of expression and thought; the interest in causal relations as distinct from interest in things for their own sake; the presentation of the results of experiment regardless of their consequence; and a loyal and tenacious adherence to those results whether they fit in with the accepted view of things or not.

These are some of the distinguishing features of the scientific method, the constituents as it were of the scientific attitude towards life. This attitude has silently but surely permeated our entire world. Its methods have, with great advantage, been applied to such different realms as philosophy, economics, sociology, and even to red-tape administration. More, science has developed a new outlook upon our environment and a new reaction to it, making some things seem more valuable and others not. We can no more ignore these new standards of science in a discussion of the general problem of values than we can ignore, say, the telephone or the Railway train. It has given us a new angle for viewing beauty and art, as modern paintings, poems and buildings, even the appointments of our homes bear out, with their dominant notes of precision, economy and exact finish. These are the gifts of Science.

It is by a synthesis to be effected by the scientist, the thinker and the artist, each bringing his own specialised contribution to the common pool, exploring the inmost recesses of human thought and activity, that our lives can be made fuller and richer and civilization truly advance.

Gentlemen, I have done. I thank you for the welcome which you have accorded to me and have great pleasure in inaugurating this session. I wish you a most successful and fruitful meeting.

VOTE OF THANKS

The following vote of thanks was moved by Lt. Colonel J. C. Chatterji, M.A., Vice-Chancellor, Agra University to Dr. Panna Lall, M.A., B.Sc., LL.B., D.Litt., C.I.E., I.C.S., Adviser to His Excellency the Governor, United Provinces :—

I rise to move a vote of thanks to Dr. Panna Lall who in spite of the multifarious duties of his exalted office and at great personal inconvenience has honoured us by his presence here this evening to preside over the inaugural session of the 11th annual meeting of the National Academy of Sciences.

I am sure I am voicing the sentiments of all present, in thanking him most warmly for the inspiring and learned address he has delivered.

He has made a most eloquent and convincing defence of modern Science at a time when so many people are severely distressed at the misuse of scientific knowledge, as illustrated by the havoc of war which holds the world in its grip. Personally I have derived considerable comfort from his championship of the Sciences.

Dr. Panna Lall has supported the claim made by another prominent Scientist, who demands that the Government of the world should be handed over to Scientists, so that the misuse of scientific knowledge may be prevented.

Being a purely Arts man the only hesitation I felt in supporting this demand was due to my not being sure as to whether Scientists had sufficient 'Sense of humour' for the job. Dr. Panna Lall himself a scientist has given such ample proof of this rare gift in his address, that so far as I am concerned I am quite prepared to hand over the Government of the World to him and his fellow scientists.

I am quite convinced that the World could not be worse governed than it is at the present time, not even by scientists.

VOTE OF THANKS

In proposing the vote of thanks to the Agra University, Prof. Shri Ranjan, M. Sc. (Cantab.), D. Sc. (State-France), F. A. Sc., F. N. A. Sc., one of the General Secretaries of the National Academy of Sciences, India, spoke as follows :—

On behalf of the Fellows and Members of the National Academy of Sciences, India, it is my pleasant duty to offer our thanks to the authorities of the Agra University for giving us the opportunity to hold our Eleventh Annual Session in the Senate Hall of the University. They have made fine arrangements for the delegates who have assembled here from all parts of India, and have given us all the facilities for holding our Sectional Meetings.

LUCKNOW February 12, 1942.

On behalf of the University of Lucknow I offer to the National Academy of Sciences best wishes for the success of its Eleventh Annual Meeting and hope that the Academy may continue to serve for many years to come the cause of Science in India through the expansion and dissemination of knowledge.

BISHESHWARY DAYAL SETH,
Lt. Col., Raja, M.L.A.,
Vice-Chancellor.

Attested.
R. R. KHANNA, M.Sc.,
Registrar,
University of Lucknow.

From

THE REGISTRAR, CALCUTTA UNIVERSITY,

To

The General Secretary,
The National Academy of Sciences,
India, Allahabad.

Senate House, the 26-2-42.

Sir,

I am desired by the Hon'ble the Vice-Chancellor and Syndicate to convey to you the good wishes of this University on the occasion of the Eleventh Annual Meeting of the National Academy of Sciences, India, to be held at Agra on the 13th, 14th and 15th February, 1942.

I have the honour to be,
Sir,
Your most obdt. Servant,
S. K. DUTT
Asst. Registrar.

Section A—Mathematics, Physics and Chemistry

PRESIDENTIAL ADDRESS

RADIATION REACTION IN RELATION TO SCATTERING PHENOMENA

By Dr. H. J. Bhabha, F.R.S.,

Indian Institute of Science, Bangalore

SUMMARY

The effect of radiation reaction on scattering phenomena both in the classical and quantum theories is discussed. When the interaction between the two colliding particles or a light quantum and a particle is a contact interaction, as is usually the case, a general argument is developed which allows one to give rigorous upper limits to the scattering cross-sections as a function of the momentum P of the field particle (light quantum or meson). It is shown that in classical theory the scattering must ultimately diminish at least as fast as P^{-2} with increasing P, whereas in the quantum theory it need only decrease ultimately as P^{-1}. These results follow on the basis of the existing theories, and any results disagreeing with them must be due to inadequate approximations in calculations. The two general results quoted above agree with the recent results of calculations on scattering phenomena both in the classical and quantum theories when radiation reaction is taken into account.

Mr. President, Fellows of the Academy, Ladies and Gentlemen, I would first like to express my thanks to the National Academy of Sciences of India for the honour it has done by inviting me to preside over the Section of Chemistry, Physics and Mathematics at the Eleventh Annual Session at Agra.

The subject of Radiation Reaction, on which I propose to speak, was one of the first to occupy the minds of physicists as soon as the ideas of the existence of the electron and its interaction with the electromagnetic field became established at about the end of the last century. The recent discovery of the meson, and the peculiarities of the interaction it is believed to have with the heavy particles, the proton and the neutron, which is such that a use of the usual method of approximation in quantum mechanical calculations leads to scattering cross-sections which increase with increasing energy of the meson, has again made this problem of the effect of the reaction of the scattered radiation on the scattering process itself one of immediate practical and theoretical interest.

The classical treatment of radiation damping for an electron was given by Lorentz, (see, for example, The Theory of Electrons, 1916). He considered an electron in which the total charge was distributed in some given way over a finite volume, $\rho(\underline{x})$ being the density of charge at the point $\underline{x}$. He then calculated the resultant of the force on this electron due to the electromagnetic fields produced at each point of the electron by the other parts of the electron, assuming the motion

of the electron at each instant to be given. For a spherically symmetrical electron moving in a straight line with a variable velocity u which is small compared with c the velocity of light, the resultant force is

$$-\tfrac{2}{3}\frac{du}{c^2dt}\iint\frac{\rho(\underline{x})\,\rho(\underline{x}')}{|\underline{x}-\underline{x}'|}\,d\underline{x}\;d\underline{x}'+\tfrac{2}{3}\frac{e^2}{c^3}\;\frac{d^2u}{dt^2}+\mathrm{O}\left(\frac{e^2\mathrm{R}}{c^4}\;\frac{d^3u}{dt^3}\right)\quad .\quad . \qquad (1)$$

R is a length of the order of the size of the electron. The first term is of the order

$$-\frac{e^2}{c^2\mathrm{R}}\;\frac{du}{dt}$$

and depends on the distribution of charge inside the electron. The expression $e^2/c^2\mathrm{R}$ has the dimensions of a mass and being multiplied by the acceleration it contributes an addition to the mechanical mass of the electron. Since this expression tends to infinity as $\mathrm{R}\to\mathrm{O}$, and the actual mass m of the electron is known from experiment, it gives a lower limit to the size of the electron, namely, $\mathrm{R}=e^2/mc^2$. For an electron of this size the electromagnetic mass would be of the same order as the observed mass, and it has for long been speculated whether the whole mass of the electron cannot be explained as of electromagnetic origin.

The only virtue of this idea is that it effects a simplification in the number of fundamental entities entering into our scheme of nature, since it dispenses with the existence of material mass as distinct from electromagnetic mass. This advantage, however, disappears when we reflect that if only electromagnetic forces operated, then the mutual repulsion of different parts of the electron would cause it to disintegrate at once, and no such stable structure could exist. Indeed, there are very great difficulties in the way of making a theory of an elementary particle with finite structure in harmony with the theory of relativity. For the shape of a particle is not a relativistically invariant concept, and in order to define it in a relativistically consistent way it is necessary to introduce a field other than the electromagnetic field, which shall be responsible for preserving the shape of the particle. Such a procedure would be artificial, and in any case very much more complicated than treating the electron as having no extension, that is, as having its total charge e located at a point.

The usual objection to the idea of a point electron is that if we start from the expression (1) and let $\mathrm{R}\to\mathrm{O}$, the electromagnetic mass of the particle becomes infinite. This difficulty is, however, not fundamental, and arises from looking upon a point electron as the limit of a finite structure. For the work which has to be done against electromagnetic forces in concentrating a finite charge e into an infinitely small volume is infinite, and manifests itself as an infinite mass. There is no reason, however, why a point electron should be regarded as a limiting case in this manner. It would also be contrary to our present views about elementary particles to look upon them as built up in this way.

It was shown by Dirac (1938) that it is possible to give a complete classical theory of a point charge moving in an electromagnetic field which is consistent with the theory of relativity. The mass of the electron appears in this theory as an arbitrary mechanical constant, the electromagnetic mass being zero. This work, therefore, removes within the limits of the classical theory all the previous objections to considering the electron as a point.

Dirac's theory is equivalent to modifying the usual expression for the energy momentum tensor $T\mu\nu$ of the Maxwell Field. That such a modification of the idea of field energy is necessary is clear for the following reason. In the static case the work done in bringing any distribution of electric charge from infinity into a given configuration can be expressed by using Maxwell's equations as energy stored in the field. If we now use the usual energy momentum tensor $T\mu\nu$ the total field energy becomes infinite if point charges are present. This is because the usual treatment includes in the work done in producing the given configuration the infinite energy which would be spent in forming the point charges. If, however, we look upon the point charges as given, then the only work which has to be done to bring the point charges into a given configuration is that against their mutual repulsions, and *is finite.* When the point charges are permanent and immutable, as is the case with elementary particles,* this is the only idea of potential energy which is physically significant. It is clear that if this energy is to be expressed as field energy, then the energy momentum tensor of the field must be different from the usual one. Pryce (1938) has shown that it is possible to reformulate the idea of field energy consistently with the theory of relativity and in such a way as to make the total energy of a given configuration of point charges finite. The usual tensor $T\mu\nu$ has to be replaced by $T\mu\nu - \frac{\partial}{\partial x_\sigma} K_{\sigma\mu\nu}$, where $K_{\sigma\mu\nu}$ is a tensor antisymmetrical in σ and μ and depends explicitly upon the co-ordinates describing the point charges present in the field. The energy tensor of the field, therefore, no longer depends only on the fieldstrengths at the points considered. With this new energy tensor the total field energy of a given configuration of point charges becomes exactly equal to their mutual potential energy in the static case. The new definition of the energy momentum tensor coincides with the usual one at large distances from all point charges where only radiation fields are concerned. The above discussion makes it clear that the procedure of Dirac and Pryce is not merely a mathematical device for getting rid of unwanted infinities in the Lorentz theory, but on the contrary directly corresponds to our present physical ideas about the nature of the elementary particles.

*We ignore such processes as pair creation and the various other nuclear transformations involving a change in the number of charged mesons or electrons, which are all obviously quantum effects and do not come within the scope of classical theory. They do not affect the above argument.

Now consider the other terms in (1). The second is independent of the size and shape of the electron, while all the succeeding terms depend on the distribution of charge in the electron explicitly and form an ascending series in powers of R. For the simple case where the electron executes a periodic motion with a frequency ν, the successive terms of (1) form a series in powers of $(R\nu/c)$. If this ratio is small, then all the higher terms are negligible compared with the second, and it can be shown that the total energy radiated by the electron is equal to the work done by a force equal to the second term. This term, therefore, represents the force which is exerted on the electron due to the radiation which the electron itself emits, that is, it represents the radiation reaction. For high frequencies, however, the higher terms in (1) also make a contribution to the radiation reaction. If we proceed to the limit $R \to 0$ all the higher terms in (1) tend to zero, except the second which remains unaffected. We should, therefore, expect that for a point electron only the second term exists.

This result agrees with the rigorous treatment of a point charge given by Dirac, in which the *exact* equation of motion of an electron is

$$m\dot{v}_\mu = e F^{in}_{\mu\sigma} v^\sigma + \tfrac{2}{3}\frac{e^2}{c^3}\left\{ \ddot{v}_\mu + v_\mu \dot{v}^2 \right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

v_μ is the four-vector giving the velocity of the particle, and a dot represents differentiation with respect to the proper time τ, while $\dot{v}^2 \equiv \dot{v}_\rho \dot{v}\rho$. $F^{in}_{\mu\sigma}$ is the "ingoing" or external electromagnetic field at the instantaneous position of the electron and is to be taken as the field that would exist at this point if the electron were absent. m is the finite mechanical mass of the electron which appears in the equations as an arbitrary constant. The further condition has to be imposed that only those solutions of equation (2) are allowed physically which remain finite at an infinitely distant time in the future, or, what amounts to the same thing, that only those solutions are permissible for which the acceleration of the electron is again zero *after* the ingoing field has died down. With this condition the solutions of equation (2) are quite definite. The term in curly brackets is the exact radiation reaction term. It is the relativistic equivalent of the second term of (1). It can be shown from dimensional arguments that the only term proportional to e^2 which could be added to equation (2) for a point electron is the second. The co-efficient 2/3 can be determined from the consideration that the energy radiated by the electron shall be equal to the work done on the electron by the ingoing field.

Dirac has shown that the cross-section for the scattering of light of frequency ν as deduced from equation (2) is

$$6\pi c^2 \frac{1}{\left(\frac{3mc^3}{2e^2}\right)^2 + \nu^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

For small frequencies the term containing ν is negligible and (3) reduces to the classical Thomson formula $\frac{8\pi}{3}\left(\frac{e^2}{mc^2}\right)^2$. For large ν the scattering is less, and in the limit of frequencies large compared with $3mc^3/2e^2$ it becomes $6\pi c^2/\nu^2$. The scattering then does not depend on the charge or mass of the particle and decreases inversely as the square of the frequency.

Following the method of Dirac, I (1940) in collaboration with Corben (1941) gave a complete classical theory of a spinning particle possessing an interaction with the Maxwell field characterised by an explicit dipole moment g_2 in addition to its charge g_1. The particle was again treated as a point. The mass m and the angular momentum I of the dipole enter the equations as arbitrary mechanical constants. The equations are very much more complicated than those of a point charge due partly to the greater number of degrees of freedom concerned. They take their simplest form when the dipole is such that it has only a pure magnetic moment in the system in which it is at rest, the electric moment in this system being zero They simplify still further when the translational motion of the dipole can be neglected, as would happen, for example, if the mass m were very large. Denoting by $\underline{M}$ a unit vector in the direction of the spin at any time, the *exact* equation for the rotation of the dipole in the rest system are (for a dipole of infinite mass)

$$I\ddot{\underline{M}}=g_2\left[\underline{M}\cdot\underline{H}\right]-\tfrac{2}{3}\frac{g_2^2}{c^3}\left[\underline{M}\cdot\ddot{\underline{M}}\right] \qquad (4)$$

$\underline{H}$ is the magnetic force of the ingoing or external field. Square brackets denote the usual vector product. The second term on the left exactly expresses the effect of radiation reaction on the motion of the dipole. It can also be derived from quite simple arguments, like the radiation reaction term in (2). The term must be quadratic in g_2, and it must be the vector product of $\underline{M}$ into some derivative of $\underline{M}$. It then follows from dimensional arguments that it must be the last term in (4), multiplied by a numerical constant. This constant can then be determined from the consideration that the energy radiated by the dipole must be equal to the work done on the dipole.

The cross-section for the scattering of radiation of frequency ν by a dipole, as derived by equation (4) is, after averaging over all initial orientations of the dipole

$$4\pi c^2\frac{\nu^2}{\left(\frac{3}{2}\frac{c^3 I}{g_2^2}\right)^2+\nu^4} \qquad (5)$$

For small ν the second term in the denominator is negligible and the cross-section shows the typical characteristic of the quantum cross-sections for the

scattering of radiation, both Maxwell or meson, by a dipole, namely, that it increases as ν^2. (5) shows, however, that for $\nu \gtrsim \sqrt{3Ic^3/2g_2{}^2}$ the effect of radiation reaction is considerable, and it ultimately reduces the scattering cross-section to $4\pi c^2/\nu^2$.

The above theories have been extended to cover neutral meson fields (Bhabha 1939, 1941). The particles which play the part of the electron in electromagnetic theory are now the "heavy particles," the proton and neutron, whose interaction with the vector meson field is characterised by the constants g_1 and g_2 the former playing the part of the charge e in electromagnetic theory, and the latter the part of a dipole moment. The essential difference between the Maxwell and a meson field is that the latter has a characteristic constant χ of the dimensions of a frequency connected when the field is quantized with the rest mass μ of the meson by $\chi=\mu c^2/\hbar$. For vector meson fields, the equations of which reduce to the Maxwell equations when $\chi=0$, and, therefore, have the closest analogy with the electromagnetic field, for each frequency and direction of propagation a longitudinally polarized wave can exist besides the two transversely polarized waves common to the Maxwell field. The cross-sections for the scattering of a *transverse* meson wave of frequency ω_0 by a point charge g_1 alone ($g_2=0$) is given by

$$6\pi c^2\left(1+\tfrac{1}{2}\frac{\chi^2}{\omega_0{}^2}\right)\frac{1}{\left(\frac{3Mc^3}{2g_1{}^2}+\frac{1}{2}\frac{\chi^3}{\omega_0{}^2}\right)^2+\left(\omega_0{}^2-\frac{3}{4}\frac{\chi^4}{\omega_0{}^2}-\frac{1}{4}\frac{\chi^6}{\omega_0{}^4}\right)} \quad . \quad . \quad (6)$$

Here M is the rest mass of the heavy particle. If $\chi=0$, this reduces to (3). It can be shown that with the actual value of the constants g_1, M and χ derived from experiment the additional terms containing χ introduce but small deviations from (3). The cross-section for the scattering of a *longitudinally* polarized wave is exactly $\chi^2/\omega_0{}^2$ times (6). It is, therefore, much smaller for $\omega_0 \gg \chi$. This is simply due to the fact that the "electro-mesic" component of a longitudinal wave is χ/ω_0 times smaller than that of a transverse wave of the same frequency and energy flow. (6) shows that for high frequencies the cross-section for transverse waves again decreases as $c^2/\omega_0{}^2$, whereas the cross-section for longitudinal waves decreases as $c^2\chi^2/\omega_0{}^4$.

The cross-section for the scattering of transverse meson waves due to the g_2 spin interaction has also been calculated (Bhabha 1941, formula 88). If we again average over all initial orientations of the dipole then the cross-section is

$$4\pi c^2\,(\omega_0{}^2-\chi^2)^2\,\frac{\alpha^2\omega_0{}^2+(\omega_0{}^2-\chi^2)^3+\chi^6}{\{\alpha^2\omega_0{}^2+(\omega_0{}^2-\chi^2)^3+\chi^6\}^2-4\alpha^2\omega_0{}^2\chi^6} \quad . \quad . \quad (7a)$$

where $\alpha \equiv 3Ic^3/2g_2{}^2$

This reduces to (5) when $\chi \to 0$. With the actual values of the constants as they occur in nature $\alpha \simeq 10\chi^2$, and hence, the explicit χ^6 terms in (7*a*) may be

neglected with an error of less than 2%. (7*a*) is a purely classical formula, but in order to compare it better with the corresponding formula given by the quantum theory it is convenient to introduce the quantities ε_P and P describing the energy and momentum of a meson, defined by $\varepsilon_P = \hbar\omega_0$, $cP = \hbar(\omega_0^2 - \chi^2)^{\frac{1}{2}}$, in which case (7*a*) may be written, neglecting the χ^6 terms,

$$4\pi \frac{P^4}{\left(\frac{3I\hbar c^3}{2g_2^2}\right)^2 \varepsilon_P^2 + P^6\hbar^{-2}} \quad . \quad . \quad . \quad . \quad . \quad (7b)$$

The second item in the denominators of formulæ (7) represents the effect of radiation reaction. For small energies, where this term is negligible, the cross-section increases proportionally to P^4/ε_P^2, exactly like the quantum cross-section. The effect of the radiation damping term is to make the cross-section decrease ultimately as $(\hbar/P)^2$, or c^2/ω^2, exactly like (5). The classical theory, therefore, shows that radiation plays a vital rôle in the scattering when

$$\omega_0^2 - \chi^2 \gtrsim \left(\frac{3}{2}\frac{Ic^3}{g_2^2}\right)^{2/3} \quad . \quad . \quad . \quad . \quad (8)$$

Putting $I=\hbar$, and giving g_2 the experimentally found value $g_2 = g_2'\hbar/\mu c$ where $g_2'^2/\hbar c \sim 1/6$, we find that radiation reaction becomes important when $E \backsim 3.5\mu c^2$. It should be noted, however, that the particular value of the energy above which the quantum formula is no longer valid is determined by the experimentally observed value of the constant g_2, and has nothing to do with the rest mass of the meson. Longitudinally polarized waves are not scattered by the spin interaction since only the "magneto-mesic" force can act on the dipole, and the magneto-mesic force of a longitudinal wave is zero.

Finally it should be mentioned that it is possible to make a classical theory of a *charged* meson field and its interaction with the heavy particles, as has been shown recently by Fierz (1941). The calculations are of particular interest in connection with the scattering of longitudinally polarized meson waves, since just for these the scattering is very small for neutral mesons, and very large for charged mesons, even in the quantum theory. The scattering of transversely polarized waves is essentially the same whether the meson field is charged or not. Fierz has shown that the cross-section for the scattering of longitudinally polarized charged meson waves is

$$4\pi \frac{P^4}{\left(\frac{\mu^2 c^2}{g_1^2}\varepsilon_P\right)^2 + P^6\hbar^{-2}} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

This is very similar to formula (7*b*). It agrees with the usual quantum-mechanical formula for small momenta. For large momenta, however, the cross-section

diminishes again as $(\hbar/P)^2$ due the effect of radiation reaction which is contained in the second term in the denominator of (9).

All classical theories agree in showing that when radiation reaction is taken into account, whether the scattering is by a point charge or a point dipole and whether the field is Maxwell or meson, the scattering cross-section for waves of frequency ω_0 ultimately decreases at least as rapidly as ω^{-2}, where $\omega = \sqrt{\omega_0{}^2 - \chi^2}$ (for light $\chi=0$). In particular cases the scattering may fall off more rapidly, for example as ω^{-4}, as happens in the scattering of neutral longitudinally polarized meson waves. Hence, $6\pi K(c/\omega)^2$ gives *an upper limit* to the cross-section where K is a dimensionless constant of order unity, and this appears to be a general property of radiation in classical theory. We shall show that it can be derived from quite general considerations.

Both the Maxwell and the meson field and their interaction with the elementary particles have this, in common, that the interactions are all "contact" interactions, that is, that the particles only interact with the field at the points at which they happen to be at any instant. This property must indeed be common to all relativistic theories since instantaneous action at a distance would violate the principle of relativity. Now consider a wave moving in a given direction of wave-number $\omega = \sqrt{\omega_0{}^2 - \chi^2}$. The Maxwell field is obtained as a special case by putting $\chi=0$. Whatever the polarization of the wave may be, we can build a wave packet of cross-sectional area $6\pi Kc^2/\omega^2$, where K is a dimensionless constant of order unity. The particle, which in all the above theories has no extension, is located at some point of space. We now suppose the wave-packet started at a large distance from the particle. If the position of the particle lies outside the tube of cross-section $6\pi Kc^2/\omega^2$ which is covered by the wave-packet in its motion, then, since the field of the wave packet is at no time appreciable at the place of the particle, obviously no interaction takes place between the particle and wave-packet, and hence no scattering results. Interaction *may* only take place if the particle lies in the tube of area $6\pi Kc^2/\omega^2$ covered by the wave-packet. Thus $6\pi Kc^2/\omega^2$ must be *an upper limit* to the scattering cross-section and our argument shows that as $\omega \to \infty$ the cross-section must decrease at least as fast as ω^{-2}. The above argument provides a proof of the general theorem stated above which was derived inductively from the results of calculations for each separate case on the basis of exact classical theories including the effects of radiation reaction.

The same argument can be extended to cover problems where quantum effects have to be taken into account and classical ideas are no longer sufficient. In quantum theory the particle which does the scattering, although still having no extension, can no longer be considered as located at a point due to the indeterminacy principle. We, therefore, consider the whole scattering process in the centre of gravity system in which the field quantum (light quantum or meson) has

a momentum p and the scattering particle the same momentum in the opposite direction. We can now make two wave-packets each of cross-sectional area of the order $6\pi\hbar^2/p^2$. If portions of the two wave-packets do not at any time overlap, then again no interaction can take place, and hence no scattering results. If they do overlap, then scattering may take place. Thus an *upper limit* to the scattering cross-section in the centre of gravity system must be $6\pi K\hbar^2/p^2$ where K is a dimensionless constant of order unity. Let μ and M be the rest masses of the field quantum and particle respectively, and ε_p and E their energies defined by $\varepsilon_p = c\sqrt{p^2+\mu^2c^2}$, $E=c\sqrt{p^2+M^2c^2}$. In experiment we usually require the scattering in the system in which the heavier particle, say that of mass M, is initially at rest. The momentum P of the lighter particle in the system, the "rest system"; is given by a Lorentz transformation, and is

$$P=p\,\frac{\varepsilon_p+E}{c^2M} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Solving the equation (10) to express p in terms of P we get

$$p^2=\frac{c^2M^2P^2}{2\varepsilon_P M+M^2c^2+\mu^2c^2} \quad . \quad . \quad . \quad . \quad (11)$$

where $\varepsilon_P=c\sqrt{P^2+\mu^2c^2}$ is the energy of the lighter particle in the rest system. Since the scattering cross-section is an area perpendicular to the velocity of transformation from one system to the other, it is invariant under this transformation. Hence in the rest system an upper limit to the scattering cross-section must also be $6\pi K\hbar^2/p^2$, which by (11) can be written

$$6\pi K\,\frac{\hbar^2(2\varepsilon_P M+M^2c^2+\mu^2c^2)}{c^2M^2P^2} \quad . \quad . \quad . \quad . \quad (12)$$

Usually $M\gg\mu$. Then if $P\ll Mc$, (12) becomes

$$6\pi K\,\frac{\hbar^2}{P^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12a)$$

This agrees with results recently obtained by Waller (1934), Heitler (1941) and Wilson (1941) on the basis of the quantum theory by taking radiation reaction into account approximately. If the heavier of the two particles be considered as fixed, that is, if we let $M\to\infty$, then (12) reduces to (12*a*) for all energies, and since $P=\hbar\omega$ we obtain the result of the classical theory given earlier. In the relativistic region for the heavier particle $P\gg Mc$ and (12) becomes

$$6\pi K\,\frac{2\hbar^2}{cMP} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12b)$$

Hence the effect of taking the momentum properties of the field, that is, of light quanta or mesons, into account is to require that the scattering cross-section shall ultimately decrease at least as fast as P^{-1} instead of P^{-2}. This again agrees with an approximate quantum mechanical treatment of radiation reaction in the relativistic region given by Wilson (1941).

Now suppose that the classical or quantum mechanical cross-section for a scattering process, calculated by neglecting radiation reaction and valid for small frequencies ω_0 is $6\pi Q$. This Q may have any arbitrary dependence on the frequency ω_0 as far as the following argument is concerned. The reasoning of the preceding paragraph has shown that (12) is always an upper limit to the cross-section. Hence the cross-section must be either $6\pi Q$ or (12) depending upon which is the smaller. Combining the two, *an upper limit* to the scattering cross-section may be written in the form

$$6\pi \frac{1}{\frac{1}{Q}+\frac{c^2M^2P^2}{K\hbar^2(2\varepsilon_P M+M^2c^2+\mu^2c^2)}} \quad . \quad . \quad . \quad . \quad (13)$$

Let us apply this to the scattering of transversely polarized neutral mesons due to the g_1 interaction alone. For very low energies both the usual classical and quantum theories neglecting radiation reaction give the "Thomson cross-section," that is

$$Q=\left(\frac{2g_1^2}{3Mc^2}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Hence, an upper limit to the cross-section in the whole range is

$$6\pi \frac{1}{\left(\frac{3Mc^2}{2g_1^2}\right)^2+\frac{c^2M^2P^2}{K\hbar^2(2\varepsilon_P M+M^2c^2+\mu^2c^2)}} \quad . \quad . \quad . \quad (15)$$

The second term in the denominator influences the cross-section appreciably only when

$$P \gtrsim \frac{3}{2}\frac{\hbar c}{g_1^2}\sqrt{K(2\varepsilon_P M+M^2c^2+\mu^2c^2)}$$

Since K is of order unity and $g_1^2/\hbar c \ll 1$, it follows that the second term is only appreciable when $P \gg Mc$, that is, in the relativistic region. In this case $\varepsilon_P \gtrsim cP \gg Mc^2$, and the above inequality simplifies to

$$P \gtrsim \frac{9}{2}K\left(\frac{\hbar c}{g_1^2}\right)^2 Mc$$

The numerical factors are of course not of any significance. Hence, in the case considered radiation reaction is effective only in the region where relativistic effects are important, a circumstance which is well known. Radiation reaction therefore

plays an important part in the classical formulae (6) (and (3)) precisely in the region where they are invalid due to their neglect of quantum effects. The formula (15), however remains valid as an upper limit, and shows that ultimately the scattering of transversely polarized mesons due to the g_1 interaction, or that of light by electrons, must decrease in the relativistic region as P^{-1}. The same result would be obtained by substituting the Klein-Nishina formula in (13) for Q. Thus radiation reaction modifies the Klein-Nishina formula so that it ultimately decreases as P^{-1} instead of $P^{-1}\log P$, as has already been noticed by Wilson (1941). In the scattering of light by electrons the preceding inequality shows that radiation reaction only becomes appreciable when $P \gtrsim (137)^2 mc$. Hence, due to quantum effects radiation reaction becomes important at much higher energies than in the classical theory, and its effect is less.

Next consider the scattering of neutral mesons due to the g_2 interaction. Neglecting radiation reaction, the quantum mechanical cross-section is given by putting *

$$Q=\left(\frac{2g_2'^2}{3\mu c^2}\right)^2 \frac{P^4}{\mu^2\varepsilon_P^2} \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

Hence an upper limit to the cross-section in the whole range of energy is given by substituting this in (13), and is

$$\frac{6\pi P^4}{\left(\frac{3\mu^2c^2}{2g_2'^2\varepsilon_P}\right)^2+\frac{c^2M^2P^6}{K\hbar^2(^2\varepsilon_P M+M^2c^2+\mu^2c^2)}} \quad \ldots \quad \ldots \quad (17)$$

The second term in the denominator ceases to be negligible when

$$\frac{cP^3}{\varepsilon_P}\gtrsim\left(\frac{3\hbar c}{2g_2'^2}\right)\frac{\mu^2c}{M}\sqrt{K\,(2\varepsilon_P M+M^2c^2+\mu^2c^2)}$$

Taking $M\approx 10\mu$ and $g_2'^2/\hbar c\sim 1/6$, this gives $P\sim 3\mu c$. Thus radiation reaction already becomes effective for $P\ll Mc$, that is, in the region where quantum effects are negligible. In this region the second term in the denominator of (17) becomes approximately $P^6/K\hbar^2$. The formula, therefore, takes the form of the classical formula (7*b*). The constant K can now be determined exactly by comparison with that formula, and is seen to be 1. There is therefore a definite region of energies defined by $\mu c<P<Mc$ in which the classical formula (7*b*) is correct while the quantum formula (16) is quite wrong. For still higher momenta $P>Mc$, the second term in the denominator of (17) is approximately equal to $cMP^5/2K^2$

* The quantum-mechanical cross-section is exactly three times the classical cross-section (7*b*) for these low energies due to differences in the averaging over the initial orientations of the dipole (Bhabha and Madhava Rao, (1941).

and the cross-section then falls of as P^{-1} instead off P^{-2}. Although (17) strictly only gives an upper limit to the scattering, the fact that it agrees closely with the exact classical cross-section (7*b*) in the whole momentum range below Mc in which the latter is valid makes it plausible to suppose that (17) also gives the scattering for $P>Mc$ with considerable accuracy. To sum up, then, the cross-section for the scattering due to the g_2 dipole interaction increases first as P^4/ε_P^2, reaches a maximum for $P\sim 3\mu c$, and then begins to decrease as P^{-2} up to $P\sim Mc$, after which it decreases as P^{-1}.

We see therefore that the use of the concept of wave-packets allows us to obtain upper limits for the magnitude of many scattering processes which are in agreement with the results of detailed calculations taking radiation reaction into account, and constitute an advance on the results previously obtained by neglecting radiation reaction. As far as the classical theory is concerned, the scattering can be calculated exactly on the basis of complete and rigorous theories, so that the only advantage of the above method is that it allows us to deduce a property of the scattering common to all the individual cases by a direct argument. As far as the quantum theory is concerned, however, the use of the concept of wave-packets has this definite advantage over the detailed calculations, namely, that it is rigorous. The treatment of radiation reaction on the quantum theory has not the same validity as that in the classical theory, since infinities occur in every calculation which have to be omitted more or less plausibly but nevertheless arbitrarily, whereas the classical theories can now be formulated in a manner unambiguously free from singularities. Moreover, the use of wave-packets shows us at once that the scattering must ultimately decrease with increasing energy even though the Hamiltonian may contain terms in the interaction which increase with increasing energy. Indeed, it has been shown (Bhabha, 1939) that the existence of such terms in the Hamiltonian by no means necessitates an increase in the scattering with increasing energy, even when radiation reaction is neglected. But it is precisely in the case of such interactions that radiation reaction may play a vital rôle in causing the scattering to ultimately decrease with increasing energy where its neglect may lead to an entirely different and fallacious result.

The mode of argument developed above is quite general, the only condition for its applicability being that the interaction between the two colliding particles shall be a contact interaction. The argument does not apply to the collision of two particles when the interaction between them takes place through the intermediary of another field, for then the particles can interact with each other even at a distance. For example, the Coulomb interaction between two charged particles is of this type, so that the general result expressed by formula (12) cannot be applied to processes where the Coulomb interaction is the essential cause of the scattering. Our general result applies, then, to the scattering of charged or neutral mesons due to their

direct interaction with a heavy particle, but *not* to their scattering due to the Coulomb field, if any, of the heavy particle.

The mode of argument developed here can be applied to the scattering of light by mesons of spin 1. The calculation of this process on the basis of the usual approximations by Booth and Wilson (1940) leads to a cross-section which *increases* as $(P/\mu c)^2$, P being the momentum of the light quantum, whereas the corresponding asymptotic behaviour of the Klein-Nishina formula is $mc \log\left(\frac{2P}{mc}\right) \Big/ P$. Our general result shows, however, that whereas the usual approximations made in calculating the scattering are sufficient in the case of electrons, since the effect of radiation reaction is here small and only replaces $mc \log\left(\frac{2P}{mc}\right) \Big/ P$ by mc/P, these approximations are inadequate for the scattering of light by mesons of spin 1 *even on the basis of the present quantum theory*, since in this case the consideration of radiation reaction is essential, ultimately causing the cross-section to decrease as $(\mu c/P)$, in agreement with a recent calculation by Wilson (1941) in which radiation reaction was considered. The generality and vigour of our result very much strengthens that of Wilson. This diminution of the Compton scattering is important, since it is connected intimately with the radiation loss of mesons. As Wilson has already noticed, it makes the radiation loss of mesons at high energies proportional to $E/\mu c^2$), E being the energy of the meson, as in the case of electrons, instead of increasing as $(E/\mu c^2)^2$, as calculations based on the usual approximations (Booth and Wilson 1940, Christy and Kusaka 1941*a*) seemed to show. That part of the greater burst production by particles of spin 1 which depends on this supposedly greater radiation loss is, therefore, illusory and it is no longer possible to conclude with Christy and Kusaka (1941*b*) by a comparison of the theoretical and experimental burst production that the mesons in cosmic radiation cannot have a spin 1.

We see, therefore, that the possible existence of elementary particles of spin greater than $\frac{1}{2}$ and the peculiarities of their interaction with the other particles and fields known in physics has made the problem of an accurate treatment of radiation reaction in the quantum theory one of immediate theoretical and practical interest. An exact treatment of this problem in the quantum theory of the same rigour and completeness as in the classical theory is still lacking.

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THE MECHANISM OF A SENSE OF PROPORTION

By Professor W. Burridge, D.M., M.A. (Oxon.),

King George's Medical College, Lucknow

This evening my subject will be the mechanism of a sense of proportion, and at the outset I find it necessary to define what I mean by a sense of proportion because otherwise it could well be urged that it is uncertain what I am talking about. The definition I give is "The attribution to ideas and things the same values as those which I give them." At the same time it is necessary for me to point out that the I in this definition does not solely refer to the I of the lecturer. Each one of you must read his own I, or ego, into it because each of us believes that the other man has a proper sense of proportion when he thinks about things as we do ourselves.

After you have sensed the significance of this definition, my next request is that each of you should take what I would term a physiological view of your brains or organs of mind. To me the brain is the machine provided for me by Nature to do my thinking, and I specially draw your attention to my use of the word, machine. Once you have appreciated the brain is the organ or machine with which you do your thinking just as your heart is a machine for pumping blood, you will be prepared to realise that the virtue of its make-up may determine how we must think. Instead of regarding our organs of mind as machines of infinite possibilities, we should realise that they must have definite limitations. For example, in a previous lecture to this academy I pointed out that the nerve cells of our brains had among their properties those possessed by a one-stringed instrument in which the string could either be slackened or tightened. Such an instrument provides us with a triple division of our ideas into the warm, cold and neutral, or the good, bad and indifferent.

Now, wherever civilisation has progressed far enough to produce philosophers, such men have speculated on the problem of good and evil, and they may well be held to have reached as many different conclusions as there have been philosophers. When, however, we realise the kind of machine with which we have been provided by Nature to do our thinking we obtain an entirely different avenue of approach to this age-old problem. We can now realise that it is primarily the make-up of the thinking-machine itself which makes us divide our ideas into the good, bad, and indifferent. In turn that provides

us with an entirely different problem concerning good and evil. Instead of pondering fruitlessly on the existence of good and evil in the world around us we have the entirely different problem of determining how certain types of ideas become associated with certain types of activity of the nerve cells which constitute our brains and how other types of ideas become associated with other types of activity. A corollary to what has just been remarked is that before anyone should be allowed in future to write any form of treatise on the problem of good and evil he should provide evidence that he knows how the machinery works that Nature provides him with to do his thinking. If that were done it is certain that there would be a considerable saving in labour, material, and thought. And if that saving were applied to such a problem as that of growing two rice plants where now they can grow one, there would certainly be much material benefit to India.

In addition I have to suggest that works dealing with philosophy, psychology, ethics, politics, etc., should have as a preamble the few sentences which I now place on the screen.

> We do not know what things are, we only know what we believe them to be. And what we believe them to be is determined for each of us by the nature of the processes mediating them to us in our brains or organs of mind. If then I believe that a particular thing is good, bad or beautiful, there must be some particular types of process at work in my brain to mediate to me the qualities of goodness, badness or beauty. We are all born to believe not only that the processes at work in our brains tell us the truth, but also that there is some external reality corresponding to that truth.

Fig. 1

If that were done much that is now written with certainty would remain unwritten or written with doubt and caution because the writer would be always faced with the problem of determining whether things really are so,

or whether he is bound to think they are so because Nature has provided him with a particular type of thinking machine.

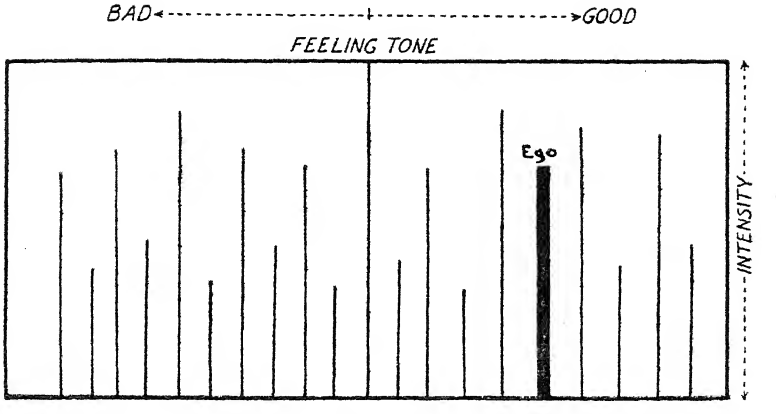

Fig. 2

I now show you on the screen a diagram representing the content of ideas of anybody's organ of mind. For convenience only good and bad ideas are shown, the good being on the right and the bad on the left. Each line in the rectangle represents an idea whose importance or intensity is indicated by the height of the line, and its feeling tone indicated by the distance from the centre.

It is a digression but nevertheless of interest to point out that if alcohol were introduced into the machinery represented above its actions would be represented by a slight increase in the height of each upstroke and a movement of everything to the right. On looking at the diagram you will appreciate that some of the normally bad ideas would thereby be made good and the very bad less bad while the original best would be moved beyond the outer boundary of the rectangle into a region where feeling tone is no longer appreciable. Those ideas are, thus, neutralised.

I would next introduce you to the formula H+L=T. This formula indicates that two sources of energy, H and L, interact to produce a thought and that they work within a certain limit T, which is indicated by the height of the rectangle. H is a source of energy giving us judging capacity and L constitutes the data that we judge. In the above diagram the intensity of data is given by the height of each line while the amount of judging capacity that can be added thereto is indicated by the distance between the top of each line and the top of the rectangle. This implies that our capacity to judge things decreases when we possess more importance. It accords with this that because each parent's children are more important to him than other people's children, his capacity to judge his

own children is less than his capacity to judge the children of others. You may also now appreciate that because alcohol increases the content of L in all our ideas it automatically diminishes our capacity to judge them.

Before leaving this part I would point out that some would call the factor H, prudence, and the factor L, passion. I prefer, however, the terminology given above.

I would now go back to Locke the philosopher. He first pointed out that any 'thing' was based on a bundle of classified and interpreted sensations or perceptions. Our ideas of the things are in Aristotelian language abstractions from those perceptions.

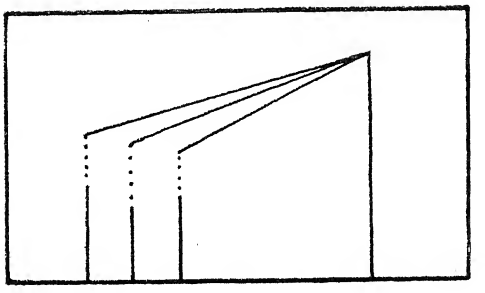

Fig. 3

In my next diagram I have endeavoured to show this process at work, and I believe it will be clearer to most of you if we consider the formation of a theory from facts. In this line the facts are represented by partly continuous and partly dotted lines while the theory is represented by the large continuous line.

It is the endeavour of every scientist to frame a theory or explanation from the facts at his disposal. The facts not only fit into the theory but also acquire less importance after the theory has been framed than they had before.

The theory, like the facts, is an energy manifestation of the organ of mind. The diagram shows the energy of the theory being derived from the energy of the facts, the portion going to the theory being indicated by the dots. The theory is, as it were, a resultant built up from energy derived from the facts.

When I give you this explanation I know that there are many scientists who would declare that I give a false picture of the relative importance of facts and theory. Scientific facts remain but scientific theories are but the shorthand expressions of those facts. This theory concerning theories is quite all right in its way, but if it were true scientists would never fight or disagree. But they do fight and disagree and when they fight and disagree, the fight does not concern the facts but the explanations or theories derived from them. Theories are thus in fact abstract ideas abstracted from the facts which fit into them. It

would not be out of place here to point out that while most people regard men, women and children as facts, they are really for each of us theories or abstractions derived from a series of coordinated sensations.

We can now get back to our original diagram and consider the ego-process. If each of you would ask yourself the simple question " Who am I ? ", you will, perhaps, start to realise that there are processes at work inside your brain to tell you who you are. Those processes are subject to the same variations as other processes. If, for example, you go to the Agra Mental Hospital you will find a number of people there who don't know who they are. And if you ask a drunk man who he is, his reply is likely to be a modification of what you would expect when he is sober.

This ego-process is a theory which originally coordinated the series of sensory impulses streaming in from all the sense-organs of the body. As we grow older more and more facts are added to this theory and so it grows in strength. In fact, it is subject to the same laws as other theory processes.

Everybody here probably believes that a theory which coordinates many facts is more important than a theory which coordinates a few, but probably few here have considered the causes of the differences. If we recall the diagram indicating theory formation given just now, you will remember that I showed the theory as a resultant derived from three facts. Well, the resultant derived from 300 facts is obviously going to be greater than the resultant derived from three. I, therefore, leave you with the problem of considering whether comprehensive theories are really the more important ones, or whether we must believe them to be so because our thinking machinery works in its own fashion.

I next ask you to consider yourself to be a statesman or ruler pondering over the affairs of the state, or even an ordinary householder pondering over the prospects of himself and his family. This pondering consists of framing a number of temporary theories built up from the conjunction of the ego-processes and the processes mediating the idea under consideration. Such theories, it may be noted, have the added property of consciousness and while framing them we estimate the importance of the idea relative to the self.

These estimates when applied to the good and bad give us a four-fold subdivision. There are those good ideas which we can look up to with respect and reverence, and there are those we can pet and fondle ; on the opposite and bad side there are the nasty things which, because they are greater than we are, provide fear and horror, and there are the nasty things we can look down on with contempt.

Now the other man has the same sense of proportion as you have when he pays respect to and cherishes the same things as you do, and when he is horrified

by the same things as you do, and agrees with you in what he holds in contempt. To attain that equality the strength of his ego-processes must be equal to yours, so also must the strength of the processes mediating all his different ideas. I consider that this equality is a mathematical possibility, but I believe that the chances of attaining it would be much less than that of being dealt two straight flushes at two consecutive games of bridge. All that can reasonably be hoped for is that you and your partner should both be strong in the same suit! But Nature provides many more suits than are to be found in an ordinary pack of cards.

But this time you may have appreciated that the strength of our ego-processes provides each of us with his standard of values. In each of us it is the measuring rod with which we measure the world in which we live. Therefore the real point to which I draw your attention is that the measuring rod has not a fixed value. There are times when we are exalted and times when we are depressed. Exaltation implies an increased strength of our ego-processes and depression a decrease, and any change in the strength of the ego-processes implies a corresponding change in the measuring rod with which we measure the world. In a state of exaltation, for example, a man may treat as contemptible what he previously feared or find himself taking a more lovely view of conventions to which he previously paid respect. In contrast with this, men when depressed or sick can give respect to what normally they only give friendly toleration.

I would next draw your attention to the point that no man with strong ego-processes can have the same degree of respect for such virtues as truth and honesty as can the man with weaker ego-processes. Indeed the former may find himself to be so important that truth and honesty are things for petting and fondling normally but to be chastised on other occasions. You may, therefore, appreciate that a statesman or a Maharaja, so long as each appreciates the importance of being a statesman or Maharaja, may well treat the truth differently from what men of lesser importance would. Many political agents, for example, find their Maharajas very difficult people to deal with.

I finally draw your attention to the cases of Hitler and Mussolini. You may hate these two men to your heart's content, yet when you get down to the facts you must admit that they are men who have done great things. And if any one here had done as much as each of them has, could he do other than believe that he was a great man? But no man can know himself to be so great as these men are without acquiring a capacity to play with ordinarily, or chastise if deemed necessary, things such as treaties which ordinary men can hold in reverence.

APPENDIX 1

Programme of the Eleventh Annual Session of the National Academy of Sciences, India

Friday, February 13, 1942

2-30 P.M.—Reception, in academic robes in a procession, of Dr. Panna Lall, D.Litt., C.I.E., I.C.S., Adviser to His Excellency the Governor of the United Provinces in the Senate Hall, Agra.

2-35 P.M.—Annual Meeting in the Senate Hall.

(1) Messages of good wishes from the Universities.
(2) Welcome Address by the Chairman of the Reception Committee.
(3) Speech by Dr. Panna Lall, D. Litt., C.I.E., I.C.S.
(4) Address by the President of the Academy.
(5) Secretaries' Report and Announcement of the Office-Bearers for 1942.
(6) Presentation of the Education Minister's Gold medal.
(7) Vote of thanks to Dr. Panna Lall, D. Litt., C.I.E., I.C.S.
(8) Vote of thanks to the University of Agra.
(9) Photograph of the Members and Delegates.

4 P.M.—"At-Home" by the Reception Committee in the University Gardens to meet Dr. Panna Lall, D.Litt., C.I.E., I.C.S., Dr. D. R. Bhattacharya, D.Sc., Ph.D., F.Z.S., F.N.I., and the Delegates of the Academy.

6-30 P.M.—Popular Lecture (illustrated by lantern slides) by Rao Bahadur B. Vishwanath, F.I.C., F.N.I., Director, Imperial Agricultural Research Institute, Delhi, in the Meston Hall, Agra College.

Saturday, February 14, 1942

10 A.M.—Presidential Address of Section I (Chemistry, Physics and Mathematics) by Dr. H. J. Bhabha, D.Sc., F.R.S., F.N.I., Indian Institute of Science, Bangalore, in the Physics Lecture Theatre, St. John's College.

11 A.M.—Meeting of Section I, Reading of and discussion on original papers.

10 A.M.—Meeting of Section II (Zoology, Botany, Geology and Agriculture) under the Presidentship of Dr. George Matthai, Sc. D., F.Z.S., F.N.I., Professor of Zoology, Punjab University, Lahore, in the Chemistry Lecture Theatre, St. John's College.

12 A.M.—Presidential Address of Section II by Dr. George Matthai.

2 P.M.—Visit to Dayal Bagh.

4-45 P.M.—Tea at Dayal Bagh.

6-30 P.M.—Popular Lecture (illustrated) by Professor W. Burridge, D. M., M.A. (Oxon.), Principal, King George's Medical College, Lucknow, on the "Mechanism of a Sense of Proportion" in the Medical College, Agra.

Sunday, February 15, 1942

2 P.M.—Excursions.

N.B.—For accommodation and other local information please write to Dr. L. P. Mathur, D.Sc., Head of the Biology Department, St. John's College, Agra.

APPENDIX 2

RECEPTION COMMITTEE

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APPENDIX 3

ABSTRACTS OF PAPERS COMMUNICATED

SECTION A

RADIAL OSCILLATIONS OF A VARIABLE STAR. *By H. K. Sen*, Mathematics Department, Allahabad University.

In a recent and important paper, Prof. A. C. Banerji has shown that no radial modes of oscillation of large amplitude are possible for a Variable Star. Adopting Prof. Banerji's method, it has been shown in this paper that no radial mode of oscillation (even of small amplitude) is possible for a sphere with a homogeneous, central core, and density at any point in the annulus varying inversely as the p^{th} power of the distance of the point from the centre. Instability of radial oscillations has also been shown for the following models: (i) a sphere with vanishingly small core, and density varying inversely as the p^{th} power of the distance from the centre ($p > 3$, and amplitude taken to be small); and (ii) a sphere in which almost the whole mass is concentrated at the centre, oscillating with large amplitude. The conclusion has been drawn that, if the density vary inversely as the p^{th} power of the distance from the centre, no radial mode of oscillation is possible except for Dr. Sterne's models (i) the homogeneous sphere and (ii) the sphere in which the density varies inversely as the square of the distance from the centre.

POLYTROPIC GAS SPHERES WITH VARIABLE INDEX. *By H. K. Sen*, Mathematics Department, Allahabad University.

Eddington's problem, of how far the properties of the variable polytrope lie between those of the limiting, uniform polytropes of maximum and minimum polytropic indices, has been considered. It has been shown from quite general considerations that the gravitational potential energy cannot be on isolated extremal property exhibited by the one-phase model of the limiting polytrope. Using Candler's equations, several intermediate properties have been deduced for the variable polytrope, besides those derived by Candler, in particular, the ratio of the central to the mean density. The temperature distribution of the variable polytrope has been considered in diverse aspects, and several integral theorems, as well as the monotonic decrease from centre to surface of certain physical variables, which is assumed for real stars, has been shown to follow from the polytropic equation.

SOLUTIONS OF THE DIFFERENTIAL EQUATIONS, $fr\ (x) = f\left(\pm\frac{1}{x}\right)$, where $f\left(\pm\frac{1}{x}\right)$ are properly defined. *By Santi Ram Mukherji*, Mathematics Department, Allahabad University.

The paper is just a generalisation of Silberstein's paper published in the *Philosophical Magazine*, September, 1940. Cases beginning from $r = 1$ to $r = 6$ have been taken and some properties of the Differential Equations in the general case have been discussed.

SOLUTIONS OF SOME DIFFERENTIAL EQUATIONS ARISING IN PROBLEMS OF VARYING VISCOSITY IN HYDRODYNAMICS. *By Santi Ram Mukherji*, Mathematics Department, Allahabad University.

The paper deals with the solutions of the following six differential equations which are required for finding the motion of incompressible fluid with varying co-efficient of Viscosity.

$$(i)\ \frac{\partial \zeta}{\partial t} = (\nu_0 + \beta_1 x)\nabla^2\zeta, \qquad (ii)\ kr\nabla^2\zeta = \frac{\partial \zeta}{\partial t},$$

$$(iii)\ kr^2\nabla^2\zeta = \frac{\partial \zeta}{\partial t} \qquad (iv)\ (c+kr)\nabla^2\zeta = \frac{\partial \zeta}{\partial t},$$

$$(v)\ (a_0+b_0 x)\nabla^2\zeta + c_0\frac{\partial \zeta}{\partial x} = 0, \qquad (vi)\ \frac{\partial V}{\partial t} = (a_0 + a_1 x + a_2 y + a_3 z)\nabla^2 V.$$

Where $\nu_0, \beta_1, a_0, b_0, c_0, a_1, a_2, a_3, k$ are definite constants.

MOTION OF AN INCOMPRESSIBLE FLUID WITH VARYING CO-EFFICIENT OF VISCOSITY GIVEN BY $\mu = \mu_0 + \epsilon_1 x$ WHERE ϵ_1 IS SMALL. *By Santi Ram Mukherji*, Mathematics Department, Allahabad University.

In this paper ϵ_1 has been taken so small that its square and higher powers are neglected and terms of the first order of quantities only have been retained. Motion of the fluid at a finite distance and at a great distance from the origin has been considered.

ON THE THEORY OF SPIRAL NEBULA. *By Brij Basi Lal*, Mathematics Department, Allahabad University.

In this paper (a) the possibility of the formation of nebulæ of irregular shapes has been considered; (b) the motion of the ejected particles along the arms of a spiral nebula has been investigated; and (c) the necessary condition for the formation of the spiral arms in a resisting medium has been found.

ON THE STRUCTURE OF THE K RADIATION OF OXYGEN. *By Dr. D. B. Deodhar and Dr. U. K. Bose*, Physics Department, Lucknow University.

In the investigations on soft X-rays of various metals with a two metre concave grating vacuum spectrograph the authors had occasionally to use the metals in the form of oxides which were rubbed upon the anticathode of the X-ray tube.

The spectograms showed lines due to the metals together with the oxygen lines. With a view to look for the origin of these oxygen lines the authors took microphotograph records of the Oxygen K line obtained on their plates. These microphotographs possessed a structure exactly similar to one observed by O'Bryan and Skinner (Proc. Roy. Soc. A Vol. 176, 1940) for oxygen in Oxides. The oxygen lines examined by the authors on their plates must have been therefore emitted by Oxygen atoms in the state of combination as oxides and not by free oxygen atoms.

IMPROVEMENT OF NITROGEN STATUS OF SOILS. *By N. R. Dhar.* Indian Institute of Soil Science, Allahabad.

In a communication to the Nature (Nature 138, 1060, 1936) it was reported that farm-yard manure (cowdung) when added to soil fixes the atmospheric nitrogen and that the value of cowdung lies not only in its nitrogen content but also in its power to fix atmospheric nitrogen. Field trials have confirmed this observation. That nitrogen fixation or accumulation on the addition of farm-yard manure takes place even in soils of temperate climate is evident from the following results obtained from the classical field trials at Rothamsted :—

	Results obtained in 1926 Total nitrogen
(1) Receiving no manure since 1845	... 0·095%
(2) Receiving farm-yard manure since 1852 ..	... 0·095%
(3) Receiving complete artificials and $(NH_4)_2SO_4$	... 0·099%
(4) Receiving complete artificials and farm-yard manure	.. 0·253%
(5) Receiving potash and phosphate but no nitrogen	... 0·090%

Our results show that the loss of nitrogen when ammonium sulphate is added to the soil is minimised by the addition of carbonaceous substances like molasses, hay, cowdung, leaves etc., which act as negative catalysts in the process of nitrification leading to a loss of nitrogen mainly in the gaseous state.

Russell ("Soil Conditions and Plant Growth, 1931, page 362) has reported that the nitrogen content of a grass-land increases from 0·152% in 1856 to 0·338% in 1912. Similarly, a land permanently covered with vegetation for 24 years showed an increase of total nitrogen from 0·108 to 0·145%.

The foregoing observations clearly show that carbonaceous substances help in the accumulation of nitrogen and its fixation and this explains why organic manures are valuable in steadying crop-yields. Not only the total nitrogen but the available nitrogen is also increased in the soils by this process.

The residual effect of stable manure as observed throughout the world may be due not mainly to the conservation of nitrogen as hitherto believed but is caused by the fixation of atmospheric nitrogen through the oxidation of energy materials like pentosans, celluloses, fats, etc. It seems that wherever a residual effect of a manure has been observed, *e.g.*, with hay or stable-manure, or molasses, it is, perhaps, chiefly due to nitrogen fixation in the soil and no residual effect will be observed with a manure which is incapable of fixing atmospheric nitrogen although it may contain carbon. This viewpoint is supported by the observation of Morse (Mass Agric. Exp. Sta. Bull., 1936, No. 333) which shows that with a nitrogen status of soils approximately 0·15% there is no nitrogen accumulation with legumes. The green manures when added to the soil slowly undergo oxidation with loss of carbonaceous substances and nitrogenous compounds. The residual alkali intensifies the loss of nitrogen from such soils and hence the nitrogen status of soils is not improved as with farm-yard manures or molasses.

It has already been reported by us that in general the available nitrogen in tropical soils is much greater (100——200 lbs. per acre) than in soils of temperate countries (20——40 lbs. per acre) and that is why a crop can be drawn in tropical soils in about 4 months whilst in non-tropical countries about 8-9 months are needed, although the total nitrogen in tropical soils is less than that in soils of temperate countries.

In temperate climates an attempt should be made to improve the available nitrogen status by ploughing the soil and exposing it to light and air in the spring, summer or autumn when the sunlight is strong. Instead of adding ammonium sulphate to soils in temperate countries to increase the available nitrogen it may perhaps be less expensive to increase ploughing and breaking

up of the soils, making conditions more favourable for oxidation and obtaining a better crop-yield without making the soil more acidic, as happens on the addition of ammonium sulphate. In the case of soils in temperate climates which have deteriorated and may have been given up for the purpose of cultivation it seems that the remedy lies in the addition of more cow-manure (farm-yard manure) or hay or other readily decomposable carbonaceous substances like molasses but not by the addition of legumes, which have no residual effect on such soils.

LOSS OF NITROGEN AND ITS RETARDATION UNDER STERILE CONDITIONS. *By N. R. Dhar and N. N. Pant.* Soil Science Institute, Allahabad.

The loss of nitrogen from urea and gelatine and in absence or presence of sugar has been investigated under completely sterile conditions when mixed with sterile soils or oxides like ZnO, TiO_2 etc. both in light and in the dark. It has been observed that even under completely sterile conditions and without any bacterial infection during the course of the experiment, there is a greater loss of nitrogen in light than in the dark and the presence of sugar markedly retards this loss. When the amount of the nitrogenous compound is not high there is appreciable fixation of nitrogen in presence of sugar. The explanation of Doryland based on the energy requirements of micro organisms (N. D. Agri. Exp. Sta. Bull., 116, 1916) is untenable in these cases and the experimental observations are easily understood from the viewpoint that just as in the case of metabolism in the animal body carbohydrates act as negative catalysts in the oxidation of proteins and can preserve the body or exogenous proteins, similarly, in the soil carbohydrates conserve protein or other nitrogenous compounds by acting as negative catalysts in the oxidation of such nitrogenous compounds. It appears that both in the soil and in the animal body oxidation processes are controlled by physico-chemical laws, as in ordinary oxidation reactions involving negative catalysis.

INVESTIGATIONS ON ALUMINIUM SILICATE SOLS. *By S. Ghosh and S. P. Srivastava,* Chemistry Department, Allahabad University.

(1) Sufficiently concentrated Sols of Aluminium Silicate containing varying amounts of Aluminium Oxide and Silica were prepared.

(2) The compositions of the different sols were between the limits of $\frac{SiO_2}{Al_2O_3} = 1{\cdot}6$ and $\frac{SiO_2}{Al_2O_3} = 0{\cdot}8$. All attempts to prepare sols containing greater or smaller SiO_2 and Al_2O_3 ratio than these values failed.

(3) All the sols containing different proportions of SiO_2 and Al_2O_3 were positively charged. Charge reversal was possible by negatively charged humic acid Sol.

(4) The sols containing greater proportions of silica yielded better gels when coagulated by monovalent anions than the sols containing less of silica and coagulated by bivalent anions.

(5) All the sols on coagulation showed (*a*) abnormal behaviour on dilution towards KCl, (*b*) ionic antagonism by mixture of KCl and other polyvalent anions and (*c*) the phenomenon of acclimatization with KCl.

With $CaCl_2$ abnormal dilution effect was developed only with the sol containing largest proportion of silica. The coagulating power of $CaCl_2$ was also least with this sol.

(6) The above results on coagulation can be explained by the views of Ghosh and Dhar from the adsorption of similarly charged ions by the colloid particles.

(7) Adsorption experiments with the different sols show that they are capable of adsorbing both the anions and cations from the added electrolytes. In general the sols containing greater amounts of silica adsorb more of cations than the sols containing less of silica, whilst the adsorption of anions increases with the increasing Al_2O_3 content of the sols.

(8) The base or acid exchange has been found to be sufficiently a slow process.

(9) These sols have been shown to be different from the sols obtained by mixing aluminium hydroxide and silicic acid sols prepared separately.

(10) The adsorption capacity of clay for both cations and anions is due to its inorganic constituent, *viz.*, silica and basic oxides. The humus considerably modifies the physical character of clay and increases its capacity to adsorb the cations.

CHEMICAL EXAMINATION OF THE SEEDS OF *Nigella sativa* Linn. (Magrel) part I. Fatty Oil. By Bawa Kartar Singh and Ram Das Tewari, Chemistry Department, Allahabad University.

In this paper the fatty oil from the seeds of *Nigella sativa* Linn. (*Magrel*) has been examined and found to contain the glycerides of oleic, linolic, myristic, palmitic and stearic acids, the percentages of which are given below:—

Oleic	35·99
Linolic	44·45
Myristic	0·26
Palmitic	6·31
Stearic	2·45
Unsaponifiable (sterol)	0·03

It has been shown that the oil examined by Crossley and Le Sueur (Agri. Ledger India, 1899, No. XII p. 34; 1911-12 p. 112) was not a volatile oil but a mixture of fatty and volatile oils. Further the diolefinic acid present in the oil of *Nigella sativa* is linolic acid in our case, whereas it is telfairic acid in the oil examined by Bures ant Mladkova (Casopis ceskoslov Lekarnictva, 10, 317—323, 1930).

SECTION B

STUDIES ON THE PHOTOCHEMICAL ACTION IN PLANTS (V) LIGHT RESPIRATION OF *EUGENIA JAMBOLANA* LEAVES AT DIFFERENT PERIODS OF STARVATION. *By Shri Ranjan and Suresh Chandra Tyagi*, Botany Department, Allahabad University.

Varying periods of previous starvation of leaves of *Eugenia jambolana*, show that the increase in light respiration is highest when the leaves are least starved. With prolong starvation the increase in light respiration decreases, till the tenth day of starvation. After the tenth day the respiration in light again increases. An analysis of the total carbohydrates shows a decrease till the tenth day and then increase. The amino-acids, on the other hand, increase up to the end of the sixth day and then decrease. Thus, some correlation has been established between the increase in light respiration and the carbohydrate content, but not with the amino-acids.

STUDIES ON THE PHOTOCHEMICAL ACTION IN PLANTS. (VI) THE EFFECT OF SOME COLOURED LIGHTS ON THE LIGHT RESPIRATION OF *EUGENIA JAMBOLANA* LEAVES. *By Shri Ranjan and Suresh Chandra Tyagi*, Botany Department, Allahabad University.

(1) The effect of monochromatic lights on the light respiration of green leaves has been investigated.

(2) Red light, which is essential for photosynthetic process, does not affect in any way the respiration rate of plants.

(3) Both the green and the blue lights increase the respiration rate of green leaves in light. The writers have shown that these lights do not affect in any way the photosynthetic process. They have thus divided the respiration of green plants into (a) dark respiration and (b) light respiration. Enzymatic activity alone is sufficient for the former, but for the latter blue, or green light is required. The rôle of the carotinoid pigments in photo-oxidative respiration is emphasised.

STUDIES ON THE LOSS OF FERTILITY BY CERTAIN FUNGI IN CULTURE. *By R. N. Tandon*, Botany Department, Allahabad University.

1. *Melanospora destruens*, *Phytophthora cactorum and Fusarium fructigenum* Strain A were maintained on a synthetic medium and on the same medium with the addition of growth producing substances (in the form of extract of lentils) and were subcultured at monthly intervals over a period of 15 months. Considerable variation was seen in each case with a tendency to a general deterioration in fertility but this could not be correlated with the medium on which the various culture lines were maintained. Work on *M. destruens* was continued for 3½ years and in general it was confirmed that the nature of medium on which the parent cultures were maintained had no correlation with these deteriorations.

2. *M. destruens* was also maintained on various modifications of the synthetic medium. The resulting cultures showed considerable variations which were largely independent of the medium on which the fungus was maintained.

3. No difference could be seen between the amount of variation in culture lines subcultured at intervals of one or of three months.

4. The type of inoculum (whether spores alone or mycelium alone) did not influence the fertility of the cultures of *M. destruens*.

5. Variation was seen in cultures developing from parts of the same hypha or from spores from the same perithecium of *M. destruens*.

6. Abundant sector formation has been shown by Malanospora cultures, pointing to the existence of strains of different intrinsic sporulating capacity.

7. Continuous subculturing of *M. destruens* over a period of 3½ years shows that in mass subculturing many poorly sporing or sterile parent cultures give rise to strongly sporing and very fertile cultures. These may remain fertile or may begin to deteriorate.

SEGMENTATION OF CAUDAL SUCKER OF THE ARHYNCHOBDELLID LEECHES. *By M. L. Bhatia* Zoology Department, Lucknow University.

There has been a good deal of controversy about the exact number of segments which form the caudal sucker of Arhynchobdellid leeches. A detailed study of a few genera belonging to this group, supported by the conditions seen in the embryos of *Hirudinaria*, reveal that *seven* segments form the caudal sucker of the Arhynchobdellid leeches.

CYTOPLASMIC INCLUSIONS IN THE OOGENESIS OF *TURDOIDES TERRICOLOR TERRICOLOR* *By D. N. Varma*, Zoology Department, Allahabad University.

The work on the cytoplasmic inclusions in the Oogenesis of birds, from the point of view of modern cytological technique, is meagre. The only papers, published after 1914, are those of Brambell in 1925, Das in 1931, Srivastava in 1933 and the latest is that of Singh in 1938. In Seven Sisters, as this bird is popularly called, the cycles of Golgi and mitochondrial bodies were traced. The phenomenon of infiltration of both Golgi bodies and mitochondria from the follicle cells to the oocyte took place in a haphazard manner and continued till the formation of Zona radiata while yolk formation took place at quite an early stage——it was even seen in the Yolk nucleus of Balbiani stage. Golgi bodies were seen to be responsible for the formation of fatty yolk and the elaboration of the albuminous yolk was found to be of seasonal occurrence. Polynuclearity was a phenomenon most extensively observed in this bird.

LIBERATION OF SEXUAL ELEMENTS IN *MARPHYSA MOSSAMBICA* PETERS. *By Najm-ud-Din Aziz*, Lahore.

In transverse sections of a mature female Polychaete belonging to the species *Marphysa mossambica* Peters, a group of well-developed eggs was seen in the cœlomic cavity. The author describes the course followed by the eggs, and discusses the mode of liberation of the sexual elements.

A COLLECTION OF OLIGOCHÆTES FROM SOME HIGH MOUNTAIN LAKES IN KASHMIR. *By Najm-ud-Din Aziz*, Lahore.

The present paper contains a preliminary account of some Oligochætes collected from 17 lakes at about 12000 ft., *viz.*, Sheshnag Handil Sar, Sona Sar, (1); Sona Sar (2), Duodhnag, Tar Sar, Chand Sar, Tulian, Harnag, Khem Sar, Yam Sar, Gangabal, Nandkol, Kul, Vishan Sar, Kishan Sar and Gad Sar. The collection includes members of the aquatic family Naididæ and of the terrestrial families Moniligastridæ and Megascolicidæ. The author also discusses the geographical distribution of these Oligochætes.

ENTOMOSTRACA FROM SOME HIGH MOUNTAIN LAKES IN KASHMIR. *By Guran Lal Arora*, Lahore.

In the present paper the author gives a short account of the Entomostraca collected from ten lakes, *viz.*, Tulian, Harnag Yam Sar, Khem Sar, Vishan Sar, Kishan Sar, Gad Sar, Gangabal, Kul and Nandkol, all situated at about 12000 ft. and fed by water from the glaciers above.

The Entomostraca include Cladocera belonging to the families Daphnidæ, Chydoridæ and Macrothridæ; Ostracoda belonging to the family Cyprididæ; and Copepoda belonging to the families Centropagidæ and Cyclopidæ. It is interesting to note that in the clear water of these lakes, at such great altitudes the Copepoda were deep red or orange, the Ostracods green and the Cladocerans dark brown, light brown or white in colour.

A PRELIMINARY REPORT ON SOME AQUATIC INSECTS FROM KASHMIR. *By D. R. Puri*, Lahore.

The collection includes approximately forty species belonging to the orders Odonata, Ephemeroptera, Coleoptera, Trichoptera and Diptera.

The order Odonata is represented by about twelve species, which were collected mostly from the Liddar Valley at altitudes ranging from 7000 ft. to 9000 ft. A few species were restricted to particular areas, while others were more widely distributed.

Three species of May-flies (Ephemeroptera) were collected from Kishan Sar and Nand Kol lakes.

The order Coleoptera includes an amphibious beetle from Gangabal lake. It floats on the surface of water, but frequently flies to the land.

There are about fifteen species of caddis flies (Trichoptera) in the collection. All species, except one, were taken on light.

Three species of crane-flies (Diptera) were collected from below Tulian lake (11000 ft.). One of them is exceptionally large, each wing having an expanse of 3 c. m.

SOME SPIDERS FROM KASHMIR. *By Sukh Dyal*, Lahore.

The present paper deals with *Campostichmma* sp. of the family Agelenidæ collected from Vishan Sar (12000 ft.) and Kishan Sar (12500 ft.) lakes. These spiders, black in colour, were found near the banks of the lakes. Another spider, *Ocyale* sp. of the family Lycosidæ, dark brown in colour, was found on the banks of Sheshnag lake (11700 ft.). Two specimens of *Lycosa* sp. and one of *Araneus* were collected from Pahalgam (7000 ft.). A specimen of *Nepohila* was found at Chandanwari (8000 ft.).

A SPECIES OF INDIGENOUS FISH FROM GAD SAR LAKE, KASHMIR. *By Nazir Ahmad*, Lahore.

This paper is a preliminary report on the ecology and systematic position of an indigenous fish obtained in the summer of 1941. The fish were small in size and mottled like *Salmo fario* Linnæus. These were very active and were seen to move in shoals.

In the paper an account of the adult and fry is given.

ON A SMALL COLLECTION OF VERTEBRATES FROM HIGH ALTITUDES. *By Nazir Ahmad*, Lahore.

The collection under report was made during the summer of 1940 and 1941, from Kashmir, and comprises tadpole and adult of the toad, *Cophophryne sikkimensis* (Blyth); young and adult of the

lizard, *Leiolopisma himalayanum* (Günther); a pit viper, *Ancistrodon himalayanus* (Günther), and two rodents, *Alactaga* sp. and *Lagomys roylei* Ogilby. The present paper contains an account of the systematics and ecology of the above forms.

THE "YOLK NUCLEUS OF BALBIANI" IN THE SPIDER *LYCOSA PUNETIPES*. *By Ram Saran Das*, Zoology Department, Allahabad University.

1. The yolk nucleus arises in the early oocytes in a juxtanuclear position as a hollow vesicle traversed by numerous fine intercrossing fibres.

2. In older oocytes this vesicle is surrounded on all sides by a lamellated membrane of varying thickness. This does not consist of mitochondria, but on the contrary is purely a product of cytoplasmic differentiation.

3. The Golgi bodies are fine granular elements which completely encircle the yolk nucleus. Between the outer margin of the yolk nucleus and the Golgi layer there occurs a clear zone almost completely devoid of the inclusions.

4. Vitellogenesis does not appear to be related to the yolk nucleus. The yolk nucleus persists in the vicinity of the principal nucleus in fairly advanced eggs, whereas vitellogenesis commences on the periphery.

THE GOLGI BODIES AND THE SECRETION OF FAT DROPLETS IN THE EGGS OF CERTAIN ANIMALS. *By Murli Dhar Lal Srivastava*, Zoology Department, Allahabad University.

The paper embodies the results of an attempt to investigate the relationship of the Golgi elements and fat droplets in the eggs of certain animals by means of an osmium-silver technique. The ovary is fixed in 1·5% osmic acid for twenty-four hours and subsequently impregnated with silver and treated with hydroquinone as in Cajal's method. Sections are mounted in Canada balsam directly or after extracting the fat in turpentine.

ON THE STRUCTURE AND ORIGIN OF THE CORPUS LUTEUM IN THE LIZARD *HEMIDACTYLUS FLAVIVIRIDIS* (RUPPEL). *By S. K. Dutta*, Zoology Department, Allahabad University.

There has been a fairly good amount of work on the female reproductive cycle in the class Mammalia, in which most of the study is directed to the behaviour of the corpus luteum of the ovary. But the changes undergone by the ruptured follicle have not been so intensively studied in the lower Vertebrata. This paper deals with the structural variations of the ovary in the lizard *Hamidactylus flaviviridis* (*Ruppel*). The occurrence of a corpus luteum is recorded and its histological structure described.

STUDIES ON THE SIX NEW SPECIES OF THE GENUS *NEODIPLOSTOMUM*, RAILLIET, 1919 (family *DIPLOSTOMIDÆ* POIRIER, 1886). *By P. N. Chatterji*, Zoology Department, Allahabad University.

This paper gives a description of the six new species of the genus *Neodiplostomum*, Railliet 1919 (Family *Diplostomidæ*, Poirier 1886). These species were collected from the common kite, *Buteo rufinus rufinus*, hawk, *Accipetres nisus malanoschistus*, woodpecker, *Brachypternus bengalensis bengalensis* and

Indian Koel, *Eudynamis scolopaceous* caught from the different villages near Allahabad. According to the subdivision of the genus into two subgenera by Dubois 1937 three species are included in the subgenus *Neodiplostomum*, Dubois, 1937 and the three in the subgenus *Conodiplostomum*, Dubois, 1937. The diagnostic characters of the species are given and their relationships discussed. *Neodiplostomum eudynamis* n. sp. differs remarkably from all the other species of the genus on account of the presence of three small muscular papillæ on the ventral side of the body just in front of the genital atrium. In *Neodiplostomum nisus* n. sp. the genital cone is absent, but a genital papillæ, which lies just in front of the opening of the hermaphroditic canal in the genital atrium is present.

SOME FRESH-WATER FISHES AND FISHERIES OF THE UNITED PROVINCES. *By A. J. Faruqi*, Zoology Department, Agra College, Agra.

The paper is divided into three parts. The first part deals with the four different varieties of nets and their different modifications which are used in the various parts of the province to suit varying conditions of rivers, lakes and other reservoirs of water. The following four types of nets are described:—

1. Trap-net,
2. Hand-net,
3. Drag-net and,
4. Fixed-net,

The description of each type of net includes full particulars regarding its construction and the method of using it.

The second part of the paper deals with 69 species of fishes. In each case interesting features such as market value, the time of the year when it is most abundantly caught and migratory instinct if possessed are dealt with in detail. A list of fishes with vernacular names is given at the end of the second part.

The third part deals with a general note regarding the scope of developing inland-fisheries in the Province. It is discouraging to note that the Local Government of the Province has so far adopted an indifferent attitude towards this problem whereas other Provinces have been more active in the field and fruitful results are seen in them. One of the major recommendations deals with the suggestion regarding the conversion of the Kitham Reservoir (Agra) into a piscine culture station and the establishment of another big station at Narora falls (Bulandshahr). On the eastern side of the Province, natural reservoirs are in abundance and these may be utilised for stocking fishes.

An elaborate scheme for the establishment of a Fishery Department is possible only if the Local Government become interested in the question and it is hoped that once the Department is started, it will become self-supporting after a few years

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FRESH-WATER POLYZOA FROM HIGH MOUNTAIN LAKES IN KASHMIR. *By N. K. Gupta*, Lahore.

In the present paper a preliminary account of some of the encrusting species of Polyzoa probably belonging to the genus *Plumatella* Lamark, from two lakes of Kashmir, namely Ganga Bal (11714 ft.) and Nand Kol (11200 ft.) is given. At the time of collection the following aquatic temperatures were recorded: Ganga Bal 64°F, Nand Kol 59°F. It is interesting to note that no trace of any Polyzoa was found in any of the other fifteen high mountain lakes, whereas it was very common in the above-mentioned lakes.

APPENDIX 4

Council of National Academy of Sciences, 1941

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APPENDIX 5

List of Members

(Arranged Alphabetically)

*—Denotes a Fellow

†—Denotes a Fellow of the National Institute of Sciences of India

Date of Election		Alphabetical List of Members
20-4-35	† *	Ajrekar, Shripad Lakshman, B.A., I.E.S., 855 Bhamburda, Poona.
17-4-31	*	Asundi, R. K., M.Sc. (Bom.), Ph.D. (Lond.), Professor of Physics, Benares Hindu University, Benares.
1-1-30	† *	Bahl, K. N., D.Phil., D.Sc., Professor of Zoology, Lucknow University, Lucknow.
1-1-30	† *	Banerji, A. C., M.A., M.Sc., F.R.A.S., I.E.S., Professor of Mathematics, Allahabad University, Allahabad.
22-12-32	† *	Banerji, S. K., D.Sc., Meteorologist, Ganeshkhind Road, Poona 5.
20-4-36	*	Basu, N. M., D.Sc., 7 Bakshi Bazar Lane, Dacca.
17-4-31	*	Basu, Saradindu, M.Sc., Meteorologist, Meteorological Office, Civil Aerodrome, New Delhi.
31-10-35	† *	Bharadwaja, Yajnavalkya, Ph.D., Professor of Botany, Hindu University, Benares.
19-3-31	*	Bhargava, Saligram, M.Sc., Reader, Physics Department, Allahabad University, Allahabad.
17-4-31		Bhatia, K. B., I.C.S., No. 2 Secretariat Quarters, the Mall, Lucknow.
17-12-35		Bhatia, M. L., M.Sc., Lecturer in Zoology, Lucknow University, Lucknow.
21-4-33	† *	Bhatnagar, S. S., Kt., D.Sc., O.B.E., Director, Board of Scientific and Industrial Research, Commerce Department, New Delhi.
20-12-34	*	Bhattacharya, A. K., D.Sc., Chemistry Department, Allahabad University, Allahabad.
1-1-31	† *	Bhattacharya, D.R., M.Sc., Ph.D., Docteur ès Sciences, Professor of Zoology, Allahabad University, Allahabad.
20-4-36	† *	Bose N. K., Ph.D., Mathematical Officer, Irrigation Research Institute, Lahore.
20-4-36	† *	Burridge, W., D.M., M.A. (Oxon.), Professor of Physiology, Lucknow University, Lucknow.

Date of Election		Alphabetical List of Members
31-10-35	*	Chakravarty, D.N., D.Sc., Professor of Chemistry, College of Sciences, Nagpur.
10-5-35	† *	Champion, H. G., M.A., Sylviculturist, Imperial Forest Research Institute, Dehradun.
12-2-40	*	Charan, Shyama, M.A., M.Sc. (Lond.), Professor of Mathematics, Agra College, Agra.
1-1-30	† *	Chatterji, G., Rai Bahadur, M.Sc., Meteorologist, Upper Air Observatory, Agra.
17-4-31	*	Chatterji, K. P., M.Sc., A.I.C., F.C.S., Reader, Chemistry Department, Allahabad University, Allahabad.
10-5-37		Chatterji, N. G., D.Sc., H. B. Technological Institute, Cawnpore.
19-8-40		Chatterji, U. N., D.Phil. (Alld.), Lecturer, Botany Department, Agra College, Agra.
17-12-35	†	Chaudhury, K. Ahmad, M.Sc., B.A. (Cal.), D.Sc. (Edin.), Wood Technologist, Imperial Forest Research Institute, Dehradun.
25-3-39	*	Chaudhri, Rafi Mohammad, M.Sc., Ph.D. (Cantab.), Reader in Physics, Muslim University, Aligarh.
10-5-35	† *	Chopra, Brvt. Col., R. N., C.I.E., M.B., I.M.S., Director, School of Tropical Medicine, Central Avenue, Calcutta.
31-10-35		Dabadghao, V.M., Physics Department, College of Science, Nagpore.
30-7-41		Dar, J.L., M.Sc., Professor, The Fort Gwalior (C.I.).
22-12-32	*	Das, B. K., D.Sc. (Lond.). Professor of Zoology, Osmania University, Hyderabad-Deccan.
19-3-31	*	Das, Ramsaran, D.Sc., Zoology Department, Allahabad University, Allahabad.
17-12-35	*	Das Gupta, S. N., M.Sc., D.I.C., Ph.D., Reader in Botany, Lucknow University, Lucknow.
20-4-36	† *	Datta, S., D.Sc., D.I.C., Professor of Physics, Presidency College, Calcutta.
15-9-37		Dayal, Jagdeshwari, M.Sc., D.Sc., Zoology Department, Lucknow University, Lucknow.
17-4-31	*	Deodhar, D.B., Ph.D., Reader, Physics Department, Lucknow University, Lucknow.
31-10-35		Desai, M. S., M.Sc., Professor of Physics, M.T.B. College, Surat.
17-4-31	*	Dey. P. K., M.Sc., I.A.S., Principal, Government Agricultural College, United Provinces, Cawnpore.

Date of Election		Alphabetical List of Members
1-1-30	† *	Dhar, N. R., D.Sc., Docteur ès Sciences, F.I.C., I.E.S., Deputy Director of Public Instruction, U. P., Allahabad.
23-4-37		Dubey, V.S., M.Sc., Ph.D., D.I.C., Professor of Economic Geology, Hindu University, Benares.
17-4-31	† *	Dutt, S. B., D.Sc., P.R.S., Reader, Chemistry Department, Allahabad University, Allahabad.
19-3-31	*	Dutt, S. K., M.Sc., D.Sc. (Alld.), Zoology Department, Allahabad University, Allahabad.
20-4-36	*	Ganguly, P.B., D.Sc., Professor of Chemistry, Science College, P. O. Bankipur, Patna.
20-4-36	† *	Ghose, S. L., Ph.D., Professor of Botany, Government College, Lahore.
8-11-30	† *	Ghosh, J. C., D.Sc., Director, Indian Institute of Science, Bangalore.
19-3-31	† *	Ghosh, R. N., D.Sc., Physics Department, Allahabad University, Allahabad.
19-3-31	*	Ghosh, Satyeshwar, D.Sc., Chemistry Department, Allahabad University, Allahabad.
17-4-31	*	Gupta, B. M., Ph.D., Deputy Public Analyst to Government, United Provinces, Lucknow.
17-4-31		Higginbottom, Sam, D.Phil, Principal, Allahabad Agricultural Institute, Naini, Allahabad.
10-5-37	† *	Husain, M. Afzal, Khan Bahadur, M.A. (Cantab.), M.Sc., I.A.S., Vice-Chancellor, Punjab University, Lahore.
10-5-37	*	Ishaq, Mohammad, Ph.D., Physics Department, Muslim University, Aligarh.
4-9-39	† *	Joshi, A. C., D.Sc., Assistant Professor of Botany, Hindu University, Benares.
3-4-34		Joshi, A. D., Rai Bahadur, P.E.S., (Retd.), 4, Windsor Place, Lucknow.
19-8-40		Kanitkar, K. P., M.A., M.Sc., Professor of Physics, Nowrosjee Wadia College, Poona 1.
15-9-31	† *	Kichlu, P. K., D.Sc., Physics Department, Government College, Lahore.
9-2-34	† *	Kothari, D. S., M.Sc., Ph.D., Professor of Physics, Delhi University, Delhi.
3-4-34	† *	Krishna, Sri, Ph.D., D.Sc., F.I.C., Forest Biochemist, Imperial Forest Research Institute, Dehradun.

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1-1-30	† *	MacMahon, P.S., B.Sc. (Hons.), M.Sc., Professor of Chemistry, Lucknow University, Lucknow.
10-5-37		Mahabae, T.S., B.A., M.Sc., Biology Department, Gujarat College, Ahmedabad.
31-10-35	† *	Maheshwari, Panchanan, D.Sc., Head of the Biology Department, Dacca University, Dacca.
31-10-35	*	Mathur, K. N., D.Sc., Lecturer in Physics, Lucknow University, Lucknow.
26-11-40		Mathur, L. P., M.Sc., D.Sc., Professor of Zoology, St. John's College, Agra.
8-11-33	*	Mathur, Ram Behari, M.Sc., Ph.D., Professor of Mathematics, St. Stephenson College, Delhi.
17-12-35	† *	Matthai, George, M.A., Sc.D., F.R.S.E., I.E.S., Professor of Zoology, Punjab University, Lahore.
19-3-31	*	Mazumdar, Kanakendu, D.Sc., Physics Department, Allahabad University, Allahabad.
1-1-30	† *	Mehta, K.C., Rai Bahadur, Ph.D., M.Sc., Agra College, Agra.
19-3-31	† *	Mehra, H. R., Ph.D., Reader, Zoology Department, Allahabad University, Allahabad.
23-4-37	*	Misra, Avadh Bihari, D.Sc., D.Phil., Zoology Department, Hindu University, Benares.
20-4-35	† *	Mowdawalla, F. N., M.A., M.I.E.E., Mem. A.I.E.E., M.I.E., 301 Frere Road, Fort, Bombay.
19-3-30		Muley, B. N., M.Sc., Ph.D., Reader in Biology, D. J. Sind College, Karachi.
22-2-33	† *	Narliker, V. V., M.A., Professor of Applied Mathematics, Hindu University, Benares.
23-4-37	*	Nath, Raj, D.I.C., Ph.D., Head of the Geology Department, Hindu University, Benares.
12-2-40		Nigam, Ved Vrat, M.Sc., Research Assistant, Imperial Council Agriculture Research, Lucknow University.
20-4-35	† *	Normand, C.W.B., M.A., D.Sc., Director-General of Observatories, Poona.
31-10-35		Oak, V. G., M.Sc., I.C.S., Additional District Judge, Jhansi.
19-8-40		Pal, Noni Lal, M.Sc., Biology Department, Dacca University, Ramna, Dacca.

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16-8-35		Pande, Kedar Dat, M.Sc., Deputy Inspector of Schools, Hardoi.
17-4 31	*	Pandya, K. C., Ph.D., St. John's College, Agra.
3-4-33	† *	Parija, P.K., M.A., I.E.S., Principal, Ravenshaw College, Cuttack.
10-5-35	† *	Pinfold, Ernest Sheppard, M.A., F.G.S., Geologist, The Attock Oil Co. Ltd., Rawalpindi.
18-9-35	*	Pramanik, S. K., M.Sc., Ph.D., D.I.C., Meteorologist, The Observatory, Alipur, Calcutta.
3-4-33	† *	Prasad, Badri Nath, Ph.D., Docteur ès Sciences, Mathematics Department, Allahabad University, Allahabad.
5-10-33	*	Prasad, Gorakh, D.Sc., Reader, Mathematics Department, Allahabad University, Allahabad.
21-4-33	*	Prasad, Kamta, M.A., M.Sc., I.E.S., Professor of Physics, Science College, P. O. Bankipore, Patna.
15-9-31	† *	Prasad, Mata, D.Sc., Royal Institute of Science, Bombay.
10-5-37		Prasad, Shiva Parbati, M.A. (Cantab.), Physics Department, Science College, P. O. Bankipore, Patna.
10-5-37		Rahimullah, M., M.Sc., Lecturer in Zoology, Osmania University, Hyderabad-Deccan.
10-5-37		Rahman, Wahidur, B.Sc. (Cal.), Professor of Physics, Osmania University, Hyderabad-Deccan.
20-12-34		Rai, Ram Niwas, M.Sc., Physics Department, Allahabad University, Allahabad.
15-9-37		Raina, Shyam Lal, M.Sc., Professor of Biology, S. P. College, Srinagar, Kashmir.
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10-5-37	† *	Rangaswami Ayyangar, G. N., Rao Bahadur, B.A., I.A.S., Millets Specialist to the Government of Madras, Agricultural Research Institute, P.O. Lawley Road, Coimbatore.
19-3-31	*	Ranjan, Shri, M.Sc. (Cantab.), Docteur ès Sciences, T.A.Sc., Professor of Botany, Allahabad University, Allahabad.
15-9-31	*	Rao, A. Subba, D.Sc., Zoology Department, Central College, Bangalore.
20-4-35	*	Rao, I. Rama Krishna, M.A., Ph.D., D.Sc., Physics Department, Andhra University, Waltair.

Date of Election		Alphabetical List of Members
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22-2-33	† *	Ray, Bidhubhusan, D.Sc., 92 Upper Circular Road, Calcutta.
10-5-37		Ray, Ramesh Chandra, D.Sc., F.I.C., Professor of Chemistry, Science College, P. O. Bankipore, Patna.
23-4-37		Rode, K. P., M.Sc., Assistant Professor of Geology, Hindu University, Benares.
1-1-30	† *	Saha, M. N., D.Sc., F.R.S., F. Inst. P., P.R.S., Palit Professor of Physics, University College of Science, 92 Upper Circular Road, Calcutta.
1-1-30	*	Sahni, B., D.Sc., Sc.D., F.G.S., F.R.S., Professor of Botany, Lucknow University, Lucknow.
1-2-36	*	Saksena, Ram Kumar, D.Sc. (State-France), Reader, Botany Department, Allahabad University, Allahabad.
17-4-31	*	Sane, S. M., B.Sc., Ph.D., Reader, Chemistry Department, Lucknow University, Lucknow.
10-5-37	*	Sayeeduddin, M., M.A., B.Sc., Professor of Botany, Osmania University, Hyderabad-Deccan.
31-10-35	† *	Sen, Jitendra Mohan, M.Ed., B.Sc., D.Ed., Teacher's Dip., F.R.G.S., Principal, Krishnagar College, Krishnagar.
3-4-33	*	Sen, K.C., D.Sc., Officer-in-Charge, Animal Nutrition Section, Imperial Veterinary Research Institute, Izatnagar, U. P.
20-4-35	† *	Sen, Nikhil Ranjan, D.Sc., Professor of Mathematics, 92 Upper Circular Road, Calcutta.
17-12-35	† *	Sen Gupta, N. N., Ph.D., Professor of Psychology, Lucknow University, Lucknow.
20-12-34	*	Sen Gupta, P. K., D.Sc., Assistant Meteorologist, Indian Meteorological Office, Alipur, Calcutta.
19-3-31	*	Sethi, Nihal Karan, D.Sc., Agra College, Agra.
31-10-35	*	Shabde, N. G., D.Sc., Professor of Mathematics, College of Sciences, Nagpur.
15-9-31		Sharma, Ram Kishore, M.Sc., Head of the Physics Department, Ewing Christian College, Allahabad.
3-4-33	† *	Siddiqi, M. R., Ph.D., Professor of Mathematics, Osmania University, Hyderabad-Deccan.
3-4-33	*	Siddiqui, Mohammad Abdul Hamid, M.A., M.Sc., F.R.C.S., D.L.O., Professor of Anatomy, King Edward Medical College, Lahore.

Date of Election		Alphabetical List of Members
10-5-37	† *	Singh, Bawa Kartar, M.A. (Cantab.), Sc.D., F.I.C., I.E.S. (Retd.), Professor of Chemistry, Allahabad University, Allahabad.
17-12-35	*	Singh, Bhola Nath, D.Sc., Kapurthala, Professor of Agricultural Botany and Plant Physiology, Hindu University, Benares.
18-9-35	*	Srivastava, Bishwambhar Nath, M.Sc., D.Sc. (Alld.), Lecturer, Physics Department, Allahabad University, Allahabad.
4-9-39		Srivastava, Girja Dayal, M.Sc., Lecturer, Botany Department, Allahabad University, Allahabad.
19-3-31	† *	Srivastava, P. L., Rai Sahib, M. A., D.Phil. (Oxon.), Reader, Mathematics Department, Allahabad University, Allahabad.
10-8-33	*	Srivastava, R. C., B.Sc. (Tech.), Sugar Technologist, Imperial Council of Agricultural Research, India, Cawnpore.
15-9-31	*	Srikantia, C., B.A., D.Sc. (Zurich), Medical College, Mysore.
19-12-32	*	Strang, J. A., M. A., B.Sc., Professor of Mathematics, Lucknow University, Lucknow.
20-4-36	*	Sur, N. K., D.Sc., Meteorologist, Meteorological Department, Alipur, Calcutta.
17-12-35		Tandon, Amar Nath, M.Sc., D.Phil., Physics Department, Allahabad University, Allahabad.
9-11-35		Tandon, Prem Narain, M.Sc., I.C.S., Under-Secretary to Govt., Political and Applt. Department, Patna.
27-9-40		Tandon, Ram Narain, Ph.D. (Lond.), F.N.A.Sc., Botany Department, Allahabad University.
4-9-39		Tewari, Sri Govind, Capt., M.A., Mathematics Department, Allababad University, Allahabad.
19-3-31		Toshniwal, G. R., M.Sc. (Alld.), D.Sc. (Alld.), Mem. I.R.E., Physics Department, Allahabad University, Allahabad.
3-4-34		Varma, Rama Shanker, M.Sc., Christ Church College, Cawnpore.
9-2-34		Vaugh, Mason, B.Sc. (Ing.), Agricultural Engineer, Allahabad Agricultural Institute, Naini, Allahabad.
19-3-31	† *	Vijayaraghavan, T., D.Phil., Reader, Mathematics Department, Dacca University, Ramna, Dacca.
20-4-35	† *	Viswanath, B., Rao Bahadur, F.I.C., F.C.S., Director, Imperial Agricultural Research Institute, New Delhi.
20-4-35	† *	Wadia, D.N., M.A., B.Sc., F.G.S., F.R.G.S., Mineralogy Department, Colombo, Ceylon.

N. B.—The Secretaries will be highly obliged if the members will kindly bring to their notice errors, if there be any, in their titles, degrees, and addresses.

APPENDIX 6

List of Exchange Journals

INDIAN

Publishers	Journals
BANGALORE	
The Indian Academy of Sciences	Proceedings of the Indian Academy of Sciences, Section A
,,	,, Section B
The Indian Institute of Science	Journal of the Indian Institute of Science, Section A
,,	,, Section B
,,	Quarterly Journal of the Indian Institute of Science
,,	Current Science
Department of Electrical Technology, Indian Institute of Science	Electrotechnics
Society of Biological Chemists, India	Proceedings of the Society of Biological Chemists, India
BOMBAY	
Haffkine Institute	Report of the Haffkine Institute
CALCUTTA	
Asiatic Society of Bengal	Journal of the Asiatic Society of Bengal (Letters)
,,	Journal of the Asiatic Society of Bengal (Science)
,,	Year-Book
,,	Journal and Proceedings of the Asiatic Society of Bengal
,,	Proceedings of the Indian Science Congress
National Institute of Sciences of India	Transactions of the National Institute of Sciences of India
,,	Indian Science Abstracts
,,	Proceedings of the National Institute of Sciences of India

Publishers	Journals
CALCUTTA	
National Institute of Sciences of India	Report of the Council of the National Institute of Sciences of India
Indian Association for Cultivation of Science	Indian Journal of Physics and Proceedings of the Indian Association for the Cultivation of Science
Bose Research Institute	Transactions of the Bose Research Institute
Indian Science News Association	Science and Culture
Indian Chemical Society	The Journal of the Indian Chemical Society
Oxford University Press	Indian Physico-Mathematical Journal
Calcutta University	Journal of the Department of Science
COONOR	
Nutrition Research Laboratories	Publications of the Laboratories (Publication discontinued from 1938)
MADRAS	
Department of Fisheries	Journals, Administration Report
Madras Government Museum	Bulletin of the Madras Government Museum, Natural History Section
NEW DELHI	
Industrial Research Bureau	Bulletin of the Indian Industrial Research
Imperial Council of Agricultural Research	Indian Journal of Agricultural Science
,,	Indian Journal of Veterinary Science and Animal Husbandry
,,	Scientific Monographs of the Imperial Council of Agricultural Research
,,	Agriculture and Livestock in India
,,	Annual Report
,,	Indian Farming
NAGPUR	
Nagpur University	Nagpur University Journal

Publishers	Journals
HYDERABAD (DECCAN)	
Osmania University	Journal of the Osmania University
PATNA	
Philosophical Society, Science College, Patna	Bulletin of the Patna Science College Philosophical Society
POONA	
Indian Meteorological Department	Scientific Notes
,,	Memoirs of the Indian Meteorological Department
,,	Seismological Bulletin

FOREIGN

AUSTRALIA

ADELAIDE	
The Royal Society of South Australia	Transactions of the Royal Society of South Australia
EAST MELBOURNE	
Council for Scientific and Industrial Research	Journal of the Council for Scientific and Industrial Research
,,	Pamphlet of the Council for Scientific and Industrial Research
,,	Annual Report
Radio, Research Board Council for Scientific and Industrial Research	Bulletin of the Radio Research Board
MELBOURNE	
Royal Society of Victoria	Proceedings of the Royal Society of Victoria
,,	Annual Report
SYDNEY	
Royal Society of New South Wales	Journal and Proceedings of the Royal Society of New South Wales

Publishers	Journals
AUSTRIA	
VIENNA	
Akademie der Wissenschaften	Anzeiger (Mathematisch-naturwissenschaftliche Klasse)
„	Anzeiger (Philosophisch-historische Klasse)
„	Almanach
BELGIUM	
BRUSSELS	
L'Academie Royale de Belgique	Bulletin de la Classe des Sciences
„	Annuaire de l'Academie Royale de Belgique
CANADA	
OTTAWA	
The Royal Society of Canada	Transactions of the Royal Society of Canada
„	Biological Sciences
The National Research Council	Annual Report
TORONTO	
The Royal Astronomical Society of Canada	Journal of the Royal Astronomical Society of Canada
VICTORIA	
The Dominion Astrophysical Observatory	Publications of Dominion Astrophysical Observatory
CHINA	
NANKING	
National Research Institute of Biology, Academia Sinica	Sinensia
Zoological Society of China, Academia Sinica	Chinese Journal of Zoology
National Research Institute of Chemistry, Academia Sinica	Memoir of the National Research Institute of Chemistry
SHANGHAI	
National Research Institute of Physics, Academia Sinica	Scientific Papers of the National Research Institute of Physics

Publishers	Journals
DENMARK	
COPENHAGEN	
Det Kgl. Danske Videnskabernes Selskab	Mathematisk-fysiske Meddelelser
„	Biologiske Meddelelser
L'Academie Royale des Sciences et des Letters de Denmark	Mémoires de l'académie Royale des Sciences et des Letters de Denmark
Laboratoire Carlsberg	Comptes-Rendus des Travaux du Laboratoire Carlsberg
EGYPT	
CAIRO	
The Egyptian Medical Association	Journal of the Egyptian Medical Association
Head of the Faculty of Medicine	Tremetodes of Fishes from Red Sea
ENGLAND	
ABERDEEN	
Imperial Bureau of Animal Nutrition	Technical Communications
ABERYSTWYTH	
Imperial Bureau of Plant Genetics ; Herbage Plants	Bulletins
ST. ALBANS, HERTS	
Imperial Bureau of Agricultural Parasitology	Helminthological Abstracts
„	Bibliography of Helminthology
CAMBRIDGE	
Imperial Bureau of Plant Genetics, School of Agriculture	Plant Breeding Abstracts
The Philosophical Society	Proceedings of the Cambridge Philosophical Society
EDINBURGH	
The Royal Society of Edinburgh	Proceedings of the Royal Society of Edinburgh

Publishers	Journals
HARPENDEN	
Imperial Bureau of Soil Science, Rothamsted Experimental Station	Technical Communications
„	Soils and Fertilizers
„	Reprints
„	Reports
„	Pamphlets
EAST MALLING, KENT	
Imperial Bureau of Fruit Production	Horticultural Abstracts
LONDON	
The Electrician, Bouverie House	Electrician
TEDDINGTON, MIDDLESEX	
The National Physical Laboratory	Reports of the National Physical Laboratory
„	Collected Researches of the National Physical Laboratory
FRANCE	
PARIS	
L'Institute Henri Poincaré	Annales de l'Institute Henri Poincaré
De La Station Biologique de Roscoff	Travaux de la Station Biologique de Roscoff
RENNES	
De La Société Scientifique de Bretagne	Bulletin de la Société Scientifique de Bretagne
GERMANY	
BERLIN	
Preussischen Akademie der Wissenschaften	Sitzungsberichte Der Preussischen Akademie
Deutschen Chemischen Gesellschaft	Berichte Der Deutschen Chemischen Gesellschaft

Publishers	Journals
GOTTINGEN	
Gasellschaften Wissenschaften zu Gottingen	Nachrichten von der Gasellschaft der Wissenschaften zu Gottingen Mathematisch-Physikalische Klasse Fachgruppe I. Mathematik
,,	,, II. Physik, Astronomie, Geophysik Technik
,,	,, III. Chemie, einschl. Physikalische Chemie
,,	,, IV. Geologie und Mineralogie
,,	,, V. Geographie
,,	,, VI. Biologie
,,	Geschaftliche Mitteilungen
HEIDELBERG	
Heidelberger Akademie der Wissenschaften	Sitzungsberichte der Heidelberger Akademie der Wissenschaften, Mathematisch-naturwissenschaftliche Klasse
LEIPZIG	
Sachsische Akademie der Wissenschaften	Berichte der Mathematische Physischen Klasse
,,	Abhandlungen der Mathematisch-Physischen Klasse
MUNCHEN	
Bayerischen Akademie der Wissenschaften zu München	Sitzungsberichte der Mathematisch-naturwissenschaftlichen Abteillung

HOLLAND

GRONINGEN	
Kapteyn Astronomical Laboratory	Publications of the Kapteyn Astronomical Laboratory
LEIDEN	
Kamerlingh Onnes Laboratory of the University of Leiden	Communications from the Physical Laboratory of the University of Leiden
,,	Communications from Kamerlingh Onnes Laboratory

Publishers	Journals
HUNGARY	
BUDAPEST	
Der Ungarischen Akademie der Wissenschaften	Mathematisher und Naturwissenschaftlicher Anzeiger
ITALY	
PALERMO	
Circolo Mathematico di Palermo	Rendiconti del Circolo Mathematico di Palermo
ROME	
International Institute of Agriculture	Monthly Bulletin of Agricultural Science and Practice
VENICE	
Centro Volpi Di Elettrologia	Bulletin of the Centro Volpi Di Elettrologia
JAPAN	
HIROSHIMA	
Hiroshima University	Journal of Science of the Hiroshima University, Series A
KEIJO	
Medical Faculty, Keijo Imperial University	The Keijo Journal of Medicine
KYOTO	
Physico-chemical Society of Japan, Kyoto Imperial University	Review of Physical Chemistry of Japan
OSAKA	
The Faculty of Science, Osaka Imperial University	Collected Papers from the Faculty of Science
"	Collected Papers from the Faculty of Medicine
SAPPORO	
The Faculty of Science, Hokkaido Imperial University	Journal of the Faculty of Science, Series I, Mathematics
SENDAI	
Imperial University of Tohoku	Science Reports of the Tohoku Imperial University

Publishers	Journals
TOKYO	
The Imperial Academy	Proceedings of the Imperial Academy
The Institute of Physical and Chemical Research	Scientific Papers
The National Research Council of Japan	Japanese Journal of Mathematics
"	Japanese Journal of Botany
"	Japanese Journal of Physics
"	Japanese Journal of Astronomy and Geophysics
"	Report
"	Report of Radio Research
The Physico-Mathematical Society of Japan	Proceedings of the Physico-Mathematical Society of Japan
MANCHOUKUO	
HSINCHING	
The Institute of Scientific Research	Report of the Institute of Scientific Research
NEW ZEALAND	
WELLINGTON	
Royal Society of New Zealand	Transactions and Proceedings of the Royal Society of New Zealand
PHILIPPINE ISLANDS	
MANILA	
Bureau of Sciences, Department of Agriculture and Commerce	Philippine Journal of Science
POLAND	
CRACOVIE	
Académie Polonoise des Sciences et des Lettres	Comptes Rendus Mensuels des Séances de la classe des Sciences Mathématiques et Naturelles
	Comptes Rendus Mensuels des Séances de la classe de Médecine

Publishers	Journals
CRACOVIE	
Académie Polonoise des Sciences et des Lettres	Bulletin International, classe des Sciences Mathématiques et Naturelles, Śerie A : Sciences Mathématiques
,,	Bulletin International, classe des Sciences Mathématiques et Naturelles, Śerie B : Sciences Naturelles (I)
,,	Bulletin International, classe des Sciences Mathématiques et Naturelles, Śerie B : Sciences Naturelles (II)
,,	Memoires, classe des Sciences Mathématiques et Naturelles, Śerie A : Sciences Mathématiques
,,	Memoires, classe des Sciences Mathématiques et Naturelles, Śerie B : Sciences Naturelles
,,	Bulletin International, classe de Médecine
,,	Memoires classe de Médecine
Polska Akademja Umiejetności	Starunia
,,	Travanx Geologiques
WARSAW	
Société des Sciences et des Lettres de Varsovie	Comptes Rendus des Śeances, class I (jezykoznawstwa i historji literatury)
,,	Comptes Rendus des Śeances, class II (historycznych, spolecznych i filozoficznych)
,,	Comptes Rendus des Śeances, class III (matematyczno-fizycznych)
,,	Comptes Rendus des Śeances, class IV (bilogicznych)
Polish Physical Society	Acta Physica Polonica
ROMANIA	
JASSY	
Universitatia Din Jasi, Seminarul Matmatic	Annals Scientifique

Publishers	Journals
SOUTH AFRICA	
CAPE TOWN	
Royal Society of South Africa	Transactions of the Royal Society of South Africa
SWEDEN	
LUND	
Kungl. Fysiografiska Sällskapets	Kungl. Fysiografiska Sällskapets Forhandlingar
STOCKHOLM	
Kungl. Svenska Vetenskapsakademie	Kungl. Svenska Vetenskapsakademiens Handlingar
UPPSALA	
Uppsala Universitet	Uppsala Universitets Årsskrift
SWITZERLAND	
GENEVA	
Société de Physique et d' Histoire Naturelle de Genève	Compte Rendu des Séances de La Société de Physique et d' Histoire Naturelle de Genève
UNION OF SOVIET SOCIALIST REPUBLICS	
KHARKOV	
Chaikovsakaya 16	Physikalische Zeitschrift der Sowjet-Union (*stopped after March, 1938*)
LENINGRAD	
The Akademie der Wissenschaften	Bulletin de l'Academie des Sciences Mathématiques et Naturelles
MOSCOW	
De l'Académie des Sciences de l'URSS	Comptes Rendus (Doklady)
De l'Académie des Sciences de l'URSS	Bulletin de l'Académie des Sciences de l'URSS classe des Sciences Mathématiques et Naturelles

Publishers	Journals
UKRAINE	
Academie des Sciences d'Ukraine, Kyive	Journal du Cycle Physique et de Chemie
„	Journal du Cycle Mathématique
„	Bulletin de la classe des Sciences Physique et Mathématiques

United States of America

ALLEGHENY CITY	
Allegheny Observatory of the University of Pittsburgh	Publications of the Allegheny Observatory
BOSTON	
American Academy of Arts and Sciences	Proceedings of the American Academy of Arts and Sciences
„	Memoirs of the American Academy of Arts and Sciences
RIO DE JANEIRO	
Instituto Oswaldo Cruz	Memorias do Instituto Oswaldo Cruz
CALIFORNIA	
The Mount Wilson Observatory	Contributions from the Mount Wilson Observatory
„	Communications from the Mount Wilson Observatory
„	Annual Report of the Director of the Mount Wilson Observatory
University Library	Publications in Zoology, University of California
Lick Observatory, University of California	Lick Observatory Bulletin
CAMBRIDGE MASS	
Massachusetts Institute of Technology	Journal of Physics and Mathematics

Publishers	Journals
CHICAGO	
The University of Chicago	Astrophysical Journal
LAWRENCE, KANSAS	
The University of Kansas	Science Bulletin
MICHIGAN	
Observatory Library, University of Michigan	Publications of the Observatory of the University of Michigan
NEW YORK	
Bell Tetephone Laboratories	Bell Telephone System Technical Publications
American Telephone and Telegraph Company	Bell System Technical Journal
Roosevelt Wild Life Forest Experiment Station	Roosevelt Wild Life Annals
The American Museum of Natural History	American Museum Novelties
New York Academy of Sciences	Annals of the New York Academy of Sciences
American Institute of Physics	Review of Scientific Instruments
,,	Journal of Chemical Physics
NEW HAVEN, YALE	
Astronomical Observatory of Yale University	Transactions of the Astronomical Observatory, Yale University
American Journal of Science	American Journal of Science
PHILADELPHIA	
The Franklin Institute of the State of Pennsylvania	Journal of the Franklin Institute
American Philosophical Society	Proceedings of the American Philosophical Society
Academy of Natural Sciences	Proceedings of the Academy of Natural Sciences of Philadelphia
,,	Miscellanea
,,	Library Annual Report

Publishers	Journals
WOODS HALE MASS	
Marine Biological Laboratory Library	The Biological Bulletin
WASHINGTON	
The National Academy of Sciences	Proceedings of the National Academy of Sciences
"	Biographical Memoirs
Smithsonian Institute	Publications
Department of Commerce, National Bureau of Standard Library	Publications of the Bureau of Standards
The Commissioner of Fisheries	Publications
Carnegie Institute of Washington	Magnetic Observations of Sun-spots

South America

MONTEVIDEO—Uruguay	Archivos De La Sociedad Biologia De
Sociedad de Biologia de Montevideo	Montevideo